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OSTEOLYTIC BONE TUMORS[1]

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THERE has been an increasing interest in recent years in the subject of the diagnosis of bone tumors, due largely to the outstanding contributions of American investigators. Because of this, however, there has also arisen a tendency to regard the subject as having arrived at the stage of ease and accuracy. Certainly, all experienced radiologists are familiar with the typical lesions, occurring at the usual age, the usual site, and having the usual appearance. It is our impression, however, that in any individual case, these normal criteria may be of no use and that even the differentiation between benign and malignant may not be possible. It is proposed to show some of the more unusual cases of osteolytic bone tumors that have come under our observation, and to discuss the roentgen findings in these groups.

1. *Classification of Osteolytic Bone Tumors:*
   - Cystic disease
   - Giant-cell tumor
   - Angioma
   - Chondroma
   - Osteogenic sarcoma: liposarcoma
   - Ewing's endotheliomyeloma
   - Multiple myeloma (solitary and diffuse)
   - Metastatic malignancy (solitary and diffuse)

A. Involvement in a systemic disease:
   - Xanthomatosis
   - Lymphogranuloma
   - Leukemia and certain anemias

B. Differential diagnosis from:
   - Cystic tuberculosis
   - Fibrocystic disease and rarefying osteomyelitis in syphilis
   - Bone changes in leprosy and Raynaud's disease
   - Bone changes in sarcoid and related lesions
   - Brodie's abscess and metastatic osteomyelitis
   - Parasitic diseases

Cystic Disease.—There are four clinical types of cystic tumors of bone:

1. The *solitary bone cyst* in patients aged from 5 to 15, usually found following a trauma.

2. *Acute bone cyst* bordering directly on the epiphyseal line on the metaphyseal side, containing giant-cell areas histologically. Some authors refer to this type as giant-cell tumors and suggest that most bone cysts are "burned-out" giant-cell tumors. Such cysts often roentgenologically have the typical appearance of the latter tumors and are indistinguishable from them.

[1] Read at the Eighteenth Annual Meeting of the Radiological Society of North America, at Atlantic City, Nov. 28–Dec. 1, 1932.

3. The typical location of *latent cyst* is in the mid-shaft of a long bone. It is presumably a cyst which developed early in life, became quiescent, and thereafter was displaced toward the mid-shaft by the growth of the bone. The patient in this condition is apt, therefore, to be older and the symptoms of longer duration. The bone near the defect may be strengthened by a thickening of the walls of the cavity. In the absence of this increase in density of the surrounding cortex it is impossible to differentiate the lesion from the rare instances of central chondroma. Metastatic malignancy or myeloma of this size would have thinned and perforated the cortex to a very considerable degree. This will be referred to later.

Figs. 1-*A* and 1-*B*. Female, aged 26. Pathologic diagnosis: Osteolytic giant-cell tumor. 1-*A*, taken Feb. 16, 1932. 1-*B*, taken Sept. 16, 1932, after deep roentgen therapy.

4. *Osteitis fibrosa cystica* already has been discussed thoroughly and our remarks will be confined to a few, concerning certain difficulties in diagnosis. In multiple myeloma there may be marked decalcification of the bones and areas of rarefaction upon which, roentgenologically, one would make the diagnosis, yet microscopically there is no tumor. Such cases have often been associated with metastatic deposits of calcium in the lung, gastric mucosa, and kidneys, characteristic of parathyroid hyperfunction (Bulger and Barr (1). Klemperer (8) reported a case of parathyroid tumor in association with carcinoma of the breast and bone metastases which certainly would have given rise to considerable confusion, if studied only roentgenologically. Determination of the serum calcium would be of diagnostic importance, since hypercalcemia is not found in metastatic malignancy, com-

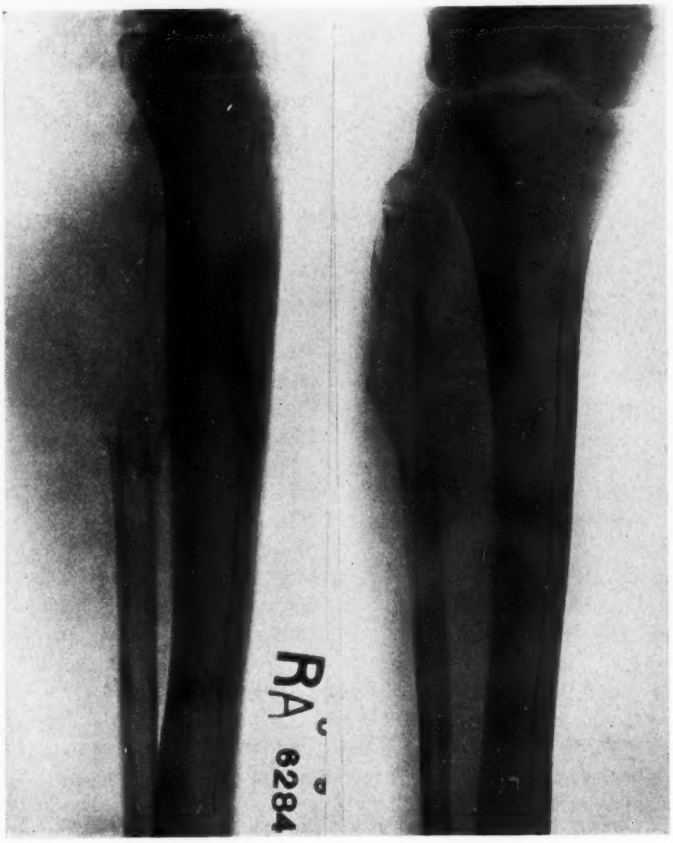
minuted fracture, nor in bone atrophy from disuse.

Giant-cell Tumor.—Roentgenologically, as Kirklin and Claude Moore (7), as well as Peirce (9), have so ably pointed out of late, the giant-cell tumors fall roughly into two groups:

1. An asymmetrical bone destruction in an epiphysis in the adult, or juxta-epiphyseal in a child, beginning subcortically and extending centrally. The expanded bone shell is extremely thin and is often soon perforated. The tumor may be trabeculated early. There is no periosteal reaction.

2. Homogeneous lysis of the central portion of the bone, the lysis extending toward the cortex so that either a thin shell of bone remains or none at all.

The present case (Fig. 1) is a female of 26 who noticed a gradually increasing swelling around the left knee about three months before this first examination. She suffered a slight trauma three weeks later but roentgen examination made elsewhere showed no bony changes. There was some fullness in the subquadriceps bursa. The pain and swelling continued and were treated locally with massage. About one month previous to the date of this report, following another relatively slight trauma, the femur was fractured and Figure 1-*A*



Figs. 2-*A* and 2-*B*. Male, aged 16. Pathologic diagnosis: Osteolytic sarcoma. 2-*A*, taken May 9, 1931. 2-*B*, taken Sept. 8, 1931, after deep roentgen therapy.

Fig. 3. Giant-cell tumor of ilium.

Fig. 4. Giant-cell tumor of skull. Arrow points to lesion. (The scratch is on the film and has nothing to do with the pathologic condition represented.)

shows practically the same appearance as that taken elsewhere immediately following fracture. It will be noted that there is an unusual degree of bone absorption about the site of fracture, with relatively little evidence of callus formation. With immobilization, the osteolysis continued and there was no evidence of bone regeneration or healing. Blood Wassermann was negative. A biopsy made at this time was considered unsatisfactory as studied at this institution. The films and history were reviewed at another institution and considered as revealing osteolytic sarcoma. However, a subsequent biopsy at this hospital showed a typical giant-cell tumor structure and the patient was treated with roentgen radiation.

The osteolysis continued (Fig. 1-*B*). The patient has passed from our observation but the family physician informs us that roentgen therapy was continued and recalcification has begun.

In general, roentgenograms in these cases give evidence of a hazy, homogeneous mass, filling the space occupied by the dissolved bone, frequently extending beyond the cortex and pushing the soft tissues ahead of it. The periosteum is not separated; there is no reactive triangle. There is no bone structure visible in the tumor. The edges of the adjacent bone appear healthy and smooth. The epiphyseal line does not act as a barrier. Of particular importance is the fact that these giant-cell tumors go on to progressive lysis, so that, as in the present case, the entire lower end of the bone is destroyed. Pathologic fracture often is the first and only symptom. It was noted in the present case that after heavy roentgen therapy, the osteolysis progressed to an even greater degree, and this has been noted before in this type of case. Yet often, if a sufficient period of time is permitted to elapse, bone regeneration does take place in most unexpected instances. This happened in a case which we judge to be similar to our own, referred to by Derr (3) at the meeting of the American Roentgen Ray Society in 1931.

The suggestion of Herendeen (6) that on these grounds roentgen therapeusis be used diagnostically must be accepted with caution. In Figures 2-*A* and 2-*B* there is demonstrated an osteolytic sarcoma, with recalcification after heavy roentgen therapy, the patient dying of pulmonary metastases three months later.

Giant-cell tumor is not necessarily confined to the end of a long bone: exceptionally it may occur elsewhere in the shaft

and it may be multiple. Besides the long bones, the bones of the face, the pelvis (Fig. 3), the skull (Fig. 4), the vertebræ, the ribs, and the tarsal bones are subject to the disease.

Angioma.—The differential diagnosis of the simple loculated type of giant-cell tumor from angioma in the long bones may be difficult. Typically the angioma occurs in the metaphysis adjacent to the epiphyseal line. Its appearance has been described as being most like that of a peculiar soap bubble. The loculations of angioma are somewhat smaller than those seen in giant-cell tumor and within them is seen a fine, fibrillary network. The tumor may extend into the marrow cavity. Pathologic fracture is very rare. The cortex is not expanded but is partially eroded so that the shell of bone may be paper-thin. The periosteum may be raised above the cortex but is intact. The appearance of angioma in a flat bone is, of course, entirely different and does not fall within the realms of this discussion.

Chondroma.—Chondroma when it occurs as the typical, small, translucent, and rarefied area centrally in the shaft of the bones of the hands or feet is not difficult to diagnose. A case was observed by us which had the unusual feature of complete perforation at one corner of the lesion. We do not believe, however, that this has any definite relationship to the pathologic report of chondromyxosarcoma. We believe that the lesion is essentially benign.

Metastatic Osteomyelitis of the Humerus.—A case (Fig. 5) is introduced at this time to demonstrate a lesion which has destroyed a large area of the cortex, has the smooth punched-out appearance of a cystic or metastatic lesion, but in which the diagnosis of metastatic osteomyelitis is made by noting the irregular bone reaction about the lesion, extending down the shaft, and the slight irregular periosteal reaction about the local lesion. The diagnosis was confirmed by operation and pathologic examination.

Osteolytic Osteogenic Sarcoma.—It appears to us that the primary malignant

Fig. 5. Metastatic osteomyelitis (operation).

osteolytic tumors of bone are best classified for roentgen diagnostic purposes into the following three groups, based on the gross and, therefore, roentgen appearance rather than on the histogenetic basis which has been so ably suggested by Geschickter and Copeland (5). We have found this grouping more useful for practical purposes.

1. *Giant-cell sarcoma (chondroblastic sarcoma).*—This type is practically indistinguishable from giant-cell tumor roentgenologically. It is usually metaphyseal in origin, early invading the epiphysis but rarely invading bone in the opposite direction. Typically, as in giant-cell tumor, it shows a central area of multilocular destruction. When the cortex is

perforated, the periosteum is raised, but there is no bone formation from its inner side. It is probably in this group that the so-called malignant giant-cell tumors belong. Ewing (4) noted that such a tumor and commonly involves the shaft of the bone either in its middle area or its metaphysis. There are areas of medullary bone destruction of a worm-eaten appearance, without any definitely circumscribed

Fig. 6. Solitary myeloma, "plasmocytoma" (pathologic diagnosis).

is from the very beginning a definite destructive process, invasive, and with the structure showing spindle cells.

2. *Osteolytic sarcoma — cartilaginous form.*—This type usually occurs in young individuals, there being a central area of irregular destruction extending through the expanded cortex, with resulting periosteal reaction. In early cases the destruction is subcortical and usually in the region of the epiphysis. The cortex is thin, later melting away. In this case the periosteal reaction may take the form of the "reactive triangle" of Kolodny. (Note Figs. 2-*A* and 2-*B*.)

3. *Osteolytic sarcoma — fibro-osseous form.*—This type usually occurs in adults margin and without new bone formation. Some of these centrally developing tumors are pathologically the malignant bone aneurysms.

Incidentally, Stewart (10), of the Memorial Hospital, has recently described three cases of perithelial, alveolar, or diffuse bone tumors, with pseudo-epithelial, spindle, or polyhedral cells, which stain with Sudan III, and are thought to take origin in the fat tissue of the marrow. There are also many giant cells present. These tumors, he feels, are best described as primary liposarcomas. In one case, there was very nearly complete destruction of the radius and partial destruction of the ulna, with pathologic fracture. Another

was an encapsulated tumor, attached to the head of the fibula, pushing the soft tissues aside, while the third was a diffuse process simulating multiple myeloma. No such cases have come under our observation. They are mentioned merely to indicate a possible further group.

Solitary Myeloma.—The roentgenologic appearance of diffuse myeloma is quite well known. As a single lesion, however, it is not common but has been reported at intervals, particularly in the English literature. It appears under various other names such as "plasmocytoma," "reticulum cell sarcoma," "primary lymphosarcoma," and "large round-cell sarcoma." These are probably all within the group of multiple myeloma which Ewing defines as a specific malignant tumor of bone marrow arising probably from a single cell type, characterized by multiple foci of origin, a uniform structure consisting of plasma cells or their derivatives, and rarely metastasizing. The solitary lesion appears as a large rounded, punched-out area extending peripherally from a central focus in the medulla. Its edges are well defined, there is no bone reaction, and there is a rapid thinning of the cortex which overlies the lesion. Early perforation occurs, followed finally by complete melting away of the cortex (Fig. 6). The lesion usually, as in metastatic carcinoma, is at the site of a nutrient artery. The lesion may be solitary or a few similar lesions may appear subsequently in other bones. Although pathologically these tumors infiltrate surrounding tissues after perforating the cortex, this is not an outstanding feature roentgenologically. When they occur at the common site of metastatic carcinoma, as, for example, the intertrochanteric region of the femur, they are indistinguishable from it. They do occur also, however, at unusual sites such as in the bones about the ankle joint and those about the elbow.

Chloroma, a rare, single, destructive lesion arising near the orbit, will simulate multiple myeloma even under the microscope. The differential diagnosis is usually made clinically.

Solitary Metastasis.—Solitary metastasis occurs with sufficient frequency to make it of considerable importance in differential diagnosis. Copeland (2) states that skeletal metastasis from carcinoma of the breast is solitary in 25 per cent of the cases. The majority of these solitary lesions occur in the vertebræ, pelvis, or femora. They are usually osteolytic. From the roentgen examinations solitary deposits were found in 60 per cent of hypernephromas metastasizing to bone. The evidence of solitary osteolytic bone metastases from carcinoma of the thyroid or lung appears to be at least as high as this, perhaps even higher. There is almost always an initial medullary involvement, with subsequent destruction of the cortex from within. There is practically no periosteal reaction. While the usual site of the tumor is at the entrance of the nutrient artery in the femur, it often occurs well above this site. Sometimes a mottling, due to increased density of bone, occurs within the area of destruction and there is thickening of the cortex above and below the site of metastasis, due to bone repair. Microscopically there are almost always both osteoblastic and osteoclastic phenomena, one or the other predominating, so that an occasional roentgen finding of the above-described character is to be expected. After deep roentgen therapy there is often evidence of considerable bone repair. The differential diagnosis of solitary metastasis from osteolytic sarcoma, particularly in the pelvis or spine, may be impossible. It is said that the sarcoma has a more definite edge separating the disease from the healthy bone and that it grows more rapidly. In the long bones, early stages of metastases are apt to be central, whereas the corresponding stages of sarcoma are apt to be subperiosteal. Since, however, the latter lesion rapidly becomes central and there do occur subperiosteal deposits of metastatic malignancy carried by the lymphatics, this differentiation is not of much practical use.

Time has permitted only the demonstration of cases of osteolytic neoplastic processes whose outstanding or only mani-

festation is in the skeletal system. These cases are some of the more unusual examples, unusual in regard to appearance, occurrence, site, or age of incidence. It is hoped that this presentation will serve to emphasize the fact that it is necessary to marshal all available data before a diagnosis is ventured from a roentgen film. The lesion should be studied with regard to whether it is single or multiple, or whether or not it is part of a systemic disease. Upon the roentgen film the appearance of the area of lysis, its location, whether central or subperiosteal, the degree to which the cortex is destroyed or expanded, the amount of periosteal reaction, the presence or absence of bone reaction are of greatest importance. In the unusual case, biopsy with thorough examination of adequate material should be resorted to early, although occasionally it is wise to prepare the lesion by deep roentgen therapy. This form of therapy certainly can do no harm and is practically always indicated in the osteolytic bone tumors. Recalcification will often occur in unexpected instances providing sufficient time is allowed but this should not be used diagnostically.

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PERICOLITIS INVOLVING THE CECUM, ASCENDING COLON, AND HEPATIC FLEXURE, FROM THE STANDPOINT OF THE SURGEON[1]

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OPERATIVE surgery has contributed in a great measure toward the solution of many diagnostic problems. The rôle which surgical exploration has played in the clarification of the pathologic basis of symptoms referable to the abdomen requires no elaboration. There is, however, one phase of abdominal involvement which has been the subject of considerable speculation and discussion—I refer to the matter of pericolitis, or pericolic membrane, more familiarly designated as Jackson's membrane, as an etiologic factor in abdominal complaints.

Jabez N. Jackson, in a paper presented before the Western Surgical Association in 1908, definitely described a membranous veil in connection with the cecum, ascending colon, and hepatic flexure which he felt was of great significance in the causation of abdominal disorders. I can do no better than quote, with his permission, some portions of his original article in which he incorporates a report by Frank Hall, pathologist to the Kansas City General Hospital, describing the condition as found at postmortem as well as on the operating table.

"The specimen of ascending colon which you have presented to me as a type of the pericolitis you have been interested in exhibits the following gross and microscopic features: The specimen presents the caput coil with attached appendix, the ascending colon, and short segment of the transverse colon.

"From a point just at the hepatic flexure to 3 in. above the caput there spreads from the parietal margin over the external lateral margin to the internal longitudinal muscle band a thin vascular veil in which long, straight, unbranching blood vessels course, most of which are parallel with each other and take a slightly spiral direction over the colon from the outer upper peritoneal attachment to the inner lower portion of the gut, ending just above the caput. The appendix is not implicated in any way.

"Coursing with the blood vessels are numbers of shining narrow bands of connective tissue which gradually broaden as they go, and end in a slight fan-shaped attachment at various points on the anterior and inner surface of the colon. At these points of attachment the gut is held in rigid plication.

"The entire specimen conveys to the eye the idea that an edematous fluid lies beneath this delicate membrane, and reminds one of nothing so much as an edematous arachnoid, so often encountered on removing the dura mater from the brain of a dead alcoholic. The colon seems placed in a diaphanous bag slightly too short to contain it without wrinkling. At the beginning of the hepatic flexure the drawn membrane particularly angulates the contained colon. Here and there are spots and tags of fat beneath the cobweb. On handling, the specimen of colon slips about in its bag without entire freedom as a fetus without its amniotic sac. A portion of the parietal peritoneum has been removed with the colon and shows that the membrane and blood vessels arise in, and are continuous with, the structures of the parietal peritoneum, as it sweeps over the colon. The entire structure seems to be peritoneum, loosed from its close connection to the abdominal wall and colonic surface by some serous exudate, after which the particular vascularization and connective tissue banding has occurred as a chronic reaction to irritative influence.

"In addition to this description we would add some observations of the condition as observed in quite a number of living subjects seen in the course of surgical operations. The transparent, vascularized veil-appearance of the membrane strikes one's attention very forcibly, with the parallel bright red vessels running with the long axis of the ascending colon. In some instances it appears as though the membrane comes on to the colon from the lateral parietal wall just above the cecum and courses directly upward, to disappear beneath the liver on the upper superior layer of the transverse mesocolon. In other instances it seems attached like an adhesion to the under surface of the liver, well anterior to the normal peritoneal reflection. Again, in other cases, it appears as though it had begun above and descended on the colon to its

[1] Presented before the Radiological Society of North America at the Seventeenth Annual Meeting, at St. Louis, Nov. 30–Dec. 4, 1931.

termination, usually just above the cecum. We have also seen it pass across and upward to the transverse colon, which, in some instances, was apparently drawn down by the membrane, practically paralleling the ascending colon to the level of the cecum. In this case the gastric symptoms were marked as a result of the mechanical gastroptosis thus produced. In one instance this membrane was so dense as to lose entirely its apparent vascularity and transparency, and it looked like a solid sheet of organized fibrous tissue, beneath which the ascending colon was so lost that it could not be seen at all until the membrane was divided and brushed aside when an apparently normal, though contracted colon became evident.

"In no instance does this membrane resemble our ordinary conception of an adhesion. It is never adherent to the abdominal wall nor to any contiguous loops of small intestine. Instead, it resembles more closely than anything we can describe a thin pterygium. In recent cases the membrane is quite free and produces but limited restriction to the underlying colon. In more advanced and characteristic cases it seems to bind the colon close to the posterior abdominal wall and produces such marked angulations and convolutions of the colon as practically to produce a stricture of its lumen; in fact, in one case seen in autopsy when a stream of water was caused to flow into the cecum through the ileocecal valve, the cecum distended almost to bursting, and yet none of the fluid would pass through the ascending colon and past the hepatic flexure until it was milked through with the fingers. It is also noteworthy that in the large majority of cases the cecum was not involved in the membrane at all; nor was the appendix invested, except when it occupied an ascending position at the outside of the colon, and then it was covered by the membrane as it was reflected on to the colon from the lateral parietal wall. The appendix in almost every case was rather small and sclerotic. We have seen the membrane in one case in which there had been, years before, an appendicular abscess, which was drained. In this case the cecum was likewise markedly involved in the membrane. The angulation of the colon is generally most marked at the hepatic flexure. There is always a very loose space where the membrane can be easily picked up at the outer angle, where it passed from the colon to the outer parietal wall."

From the description presented it becomes evident that we have under consideration a condition which offers many potentialities from the standpoint of pathogenesis in its relation to abnormal conditions involving the cecum, appendix, ascending colon, and hepatic flexure. Studies along this line have shown that these membranes are not necessarily limited to the areas mentioned; however, the portions of the intestines referred to constitute the greater number of clinical problems. The recognition and proper evaluation of pericolitis as a factor in abdominal involvement must not be overlooked by the surgeon. In many cases where an appendix has been removed upon the diagnosis of chronic appendicitis, the reason for the patient's failure to obtain relief has been the presence of a pericolic membrane which was not taken into consideration as a causative factor.

ETIOLOGY

The pathogenesis of the pericolic membrane has been the subject of considerable study. Opinions vary as the basis of their origin, but no definite conclusion has as yet been reached from the etiologic contentions which have been advanced. Studies in comparative anatomy of the abdomen reveal essential differences in abdominal structure in quadrupeds as compared to human types. In quadrupeds the liver is suspended by the mesentery and the large intestine has a long mesentery and is freely movable. In man, the liver is fused with the diaphragm and the ascending colon and the two flexures are normally fixed to the posterior abdominal wall without the intervention of a mesentery. This is apparently due to prenatal fixation in man by adhesions between the parietal and visceral peritoneum in an effort to maintain the organs mentioned in their respective positions, thereby preventing them from dropping into the lower abdomen.

From an etiologic standpoint, the causes of pericolic membrane have been divided into: (*a*) congenital, (*b*) acquired, and (*c*) inflammatory.

Congenital.—Embryologists and anato-

mists have reported the occurrence of pericolic membrane in postmortems immediately following birth.

Acquired.—The presence of pericolic membrane has been interpreted as an effort on the part of Nature to correct a developmental defect, which resulted in a failure to obtain normal fixation of the ascending colon. In normal individuals the ascending and descending colon should be fused to the parietal peritoneum in a way which practically fixes the large bowel. Embryologists and anatomists, however, have made the observation that from 20 to 40 per cent of persons do not develop normally in this respect, resulting in a mesenteric defect which most frequently involves the cecum and ascending colon—the primitive mesentery, as it were, a reversion to the normal arrangement in quadrupeds.

As a result of this defect in normal fixation of the ascending colon and depending upon the extent of this defect, varying degrees of mobility of the cecum and ascending colon result. To this unusual mobility is due visceral displacement, associated with more or less extensive membrane formation, which, as I have said before, has been regarded as an effort upon the part of Nature to compensate for a developmental defect. In many instances, this compensatory effort is successful. Very often, however, this corrective process "goes wild," thereby causing a multiplicity of organic and functional abnormalities of the bowel, with their consequent train of symptoms.

Inflammatory.—The frequent association of chronic appendicitis, colitis, and chronic involvement of the gall bladder in the presence of these membranes, and the frequent involvement of the organs mentioned by the pericolic membrane has led to the feeling that there may be an inflammatory basis for their presence.

SYMPTOMS

Although the pathologic basis for these membranes be more or less indefinite, their presence as observed by surgeons explains in a most convincing manner the possible basis for the many symptoms referable to chronic involvement of the abdominal cavity. These broad bands, by their encroachment upon the colon, frequently cause trouble at the ileocecal junction, and are capable of producing a narrowing of the lumen of the bowel, also abnormal angulation at the hepatic flexure. If very extensive, they may also involve the duodenum and jejunum: in fact, no portion of the abdomen is exempt from their influence. I do not propose to delve extensively into the symptom-complex that may result from the pernicious action of these membranes. Studies in many instances have shown that they are a definite factor in the production of intestinal stasis, ranging from mild forms of chronic constipation to severe obstruction. These membranes, in most instances, fall short of properly supporting the cecum and, as a result, we find this condition associated with enteroptosis, the functional and organic symptoms of which are familiar to clinicians. The symptomatology in many cases diagnosed as chronic appendicitis is based upon the presence of pericolic membranes involving the cecum and appendix, and the removal of the appendix has in many cases not produced the desired result because the presence of pericolitis as a factor in the production of the symptoms was overlooked. The symptoms in the presence of a pericolic membrane may simulate gall-bladder disease, chronic gastro-intestinal involvement, and even pelvic trouble; in fact, pericolic membrane may be the basis for the symptoms involving the organs mentioned.

DIAGNOSIS

The diagnosis of pericolic membrane is based on the history of the case, evaluation of the symptoms, physical examination, and x-ray study. Suggestive points in the history and symptoms include:

1. History of chronic pain and discomfort in the region of the cecum and

appendix aggravated by distention of the cecum and relieved when this distention is less pronounced or disappears.

2. Chronic constipation which is resistant to the usual corrective measures, especially when this intestinal stasis appears to be progressive in character.

3. Chronic dyspepsia which is not associated with any definite evidences of disease of the stomach or gall bladder.

4. A history of so-called nervous dyspepsia or spastic colitis which persists in the face of medical measures.

Suggestive physical findings include:

1. Findings of a definite enteroptosis in the presence of the symptoms mentioned.
2. Abnormal mobility of the cecum.
3. Abnormal fixation of the cecum.
4. Abnormal distention of the cecum.

The presence of physical signs suggestive of pathology in the right side of the abdomen, plus intestinal symptoms without any definite tenderness over the area involved, is a combination with which one frequently meets.

On deep inspiration the cecum is forced down by fixation of the colon on pressure with the left hand in the right hypochondriac region. The cecum can be palpated with the right hand and its contour, mobility, and texture satisfactorily judged.

The x-ray may be of definite value. The gastro-intestinal x-ray examination or the barium enema may reveal abnormal conditions of the cecum, kinks at the juncture of the cecum and ileum, and at the hepatic flexure, as well as narrowing or distortion of the ascending colon.

In some cases the diagnosis may rest on an exploratory laparotomy, which I feel is indicated in many cases in which gastro-intestinal symptoms of long standing fail to respond to non-surgical measures.

TREATMENT

The treatment of pericolic membrane may be along palliative and radical lines. Palliative measures in cases with persistent symptoms are, as a rule, unsatisfactory.

Radical measures properly applied are of definite value. I employ a right rectus incision, exposing the peritoneal cavity. The cecum, appendix, ascending colon, and hepatic flexure are carefully explored. The condition, location, and mobility of the areas mentioned are carefully considered and the pathologic effect of the membranes evaluated. The surgical treatment of these membranes and of the colon depends upon conditions encountered. Any abnormality met with is corrected by proper section and treatment of the offending pericolic membrane. Kinks and contractions are eliminated and every effort is made to obtain fixation of the ascending colon which will permit normal readjustment and contour. I will not at this time describe in detail the types of operations required to meet different abnormalities encountered. I wish to state, however, that my surgical management of these situations is more or less conservative. I am not greatly inclined toward "short-circuiting" operations, which in my experience with these cases I have found of practically no necessity.

In conclusion, I wish to emphasize the desirability of the consideration of surgical treatment of gastro-intestinal involvement of the chronic type which fails to respond to the ordinary non-surgical measures. I feel that the surgeon, in many of these cases, has a great deal to offer the patient in his search for relief.

THE RECORDING OF CARDIAC MOVEMENTS AND SOUNDS BY THE ROENTGEN RAY (KYMOPHONOROENTGENOGRAPHY)[1]

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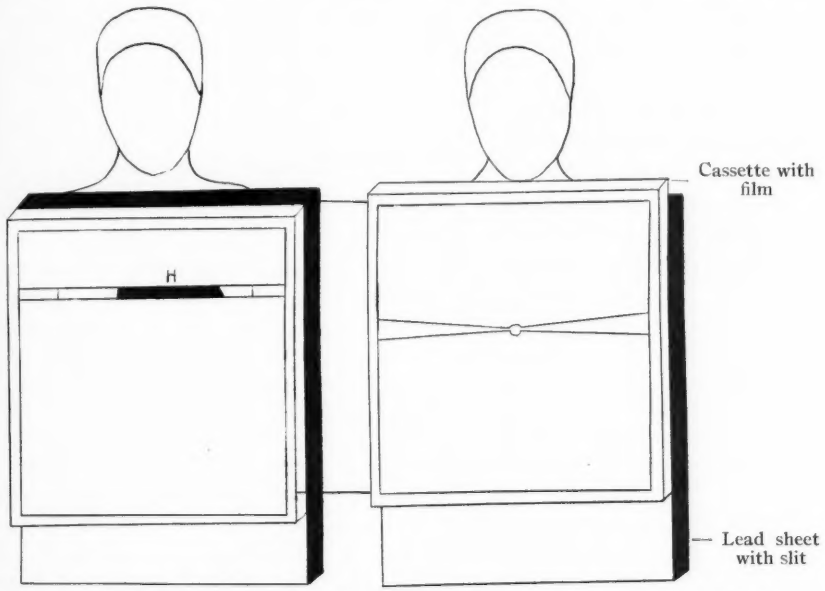
PART 1

OUR knowledge of the movements of the heart is based on animal experimentation, on transitory observations of the opened chest, and on examination by roentgen-ray methods. Fluoroscopy, technically the simplest of the roentgen methods, throws little light on this subject, because the rapidity and complexity of the movement makes an accurate analysis difficult. Cinematography, either by photography of the fluoroscopic image or by direct serial roentgenography, is impractical for routine studies and is complicated both in technic and analysis.



Figs. 1-*A* and 1-*B*. In the ordinary kymogram such as is used in the physiologic laboratories, the up-and-down movement of a lever of a tambour is recorded in the form of a wave on a moving surface (blackened drum). In the roentgen-kymogram, however, the moving pointer is replaced by the shadow of a moving portion of the heart surface and the drum by a moving photographic film. To get the movement of only a small portion of the heart surface, the chest is covered by a sheet of lead, in which there is a slit. The slit is placed opposite that portion of the heart it is desired to study. A portion of the heart as it would be disclosed on the fluoroscopic screen through the slit in a lead sheet, is shown (Fig. 1-*A*) as an expanding and contracting black band. If the fluoroscopic screen is replaced by a moving film (Fig. 1-*B*), the movement of the band of heart shadow is now recorded on the film as a shadow with serrated edges. There is no limit to the extent of the film, which may be moved in front of the slit under such conditions. However, the movement of only a single point of the right and a single point of the left heart is thus recorded. Instead of a single slit, multiple slits may be utilized (Fig. 1-*C*). A record is now obtained of the movement of multiple points on the heart surface. The movement of the film must now, however, be limited to a distance just short of the distance between slits, to avoid overlapping (Fig. 1-*D*).

There is now available, however, a sim-

[1] Read before the American Congress of Radiology, at Chicago, Sept. 25–30, 1933.

ple graphic method of obtaining a permanent record of the movements of the heart on a single film. Essentially, this method is roentgenography through a slit diaphragm placed close to the object in motion, the recording film not being at rest as in ordinary roentgenography but moving at a constant rate of speed, at right-angles to the direction of the slit. Thus if the slit is horizontal the film moves in a vertical direction; if the slit is vertical, the film moves horizontally. The motion of the object in front of the slit is recorded on the film in the form of a wave or curve.

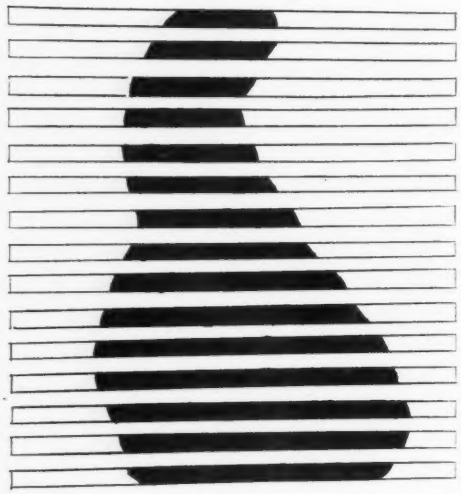


Fig. 1-*C*. (Diagrammatic.)

For the study of the movements of the heart by the single slit method the anterior thorax is placed against a lead plate having a slit several millimeters wide. By the aid of the fluoroscopic screen, the slit is so adjusted that it crosses the cardiac shadow at a desired level. The tube is placed behind the thorax, with its focal spot at the level of the slit. Fluoroscopy will now show the pulsating band-like shadow of a narrow section of the heart (Fig. 1-*A*). If the fluoroscopic screen is replaced by a film, moving at a regular rate in a direction at right-angles to the slit (Fig. 1-*B*), the moving cardiac shadow will be projected on the film as a continuous band whose edges bear waves corresponding to the movement of the particular portions of the heart exposed in the slit. The length of a record made in this way is limited only by the length of the film.

Such a single slit kymogram can trace the movement of only one or two points of the heart surface. It has the additional limitation of giving neither the general form and contour of the heart, nor the morphology of the other thoracic structures.[2]

In the multiple-slit method, the lead sheet against which the thorax is placed has many equally spaced slits (Fig. 1-*C*). The length of the record of movement, of the particular part exposed in the various slits, is now necessarily limited in order to avoid overlapping of the records (Fig. 1-*D*). The exposure is, therefore, limited to the time it takes the film to move a millimeter or so less than the distance between the slits. The length of the individual records is limited, therefore, but by making the slits narrow and decreasing the speed of motion of the film, a number of waves of each point sufficient for practical study may be obtained. By the multiple-slit method, not only is the motion of the entire heart and its vessels delineated, but

[2] This technical principle was first applied in the study of the heart action by the Polish physiologist, Sabat, in 1913, whose article on the subject attracted little attention. Later in the same year, Rosenthal (Munich), constructed a simple instrument which was used by Goett, who, in 1913, attempted an analysis of cardiac movements by this method. They used one and two slits.

In 1916, A. W. Crane in a paper on "Roentgenology of the Heart" reported studies made by this method and compared them with polygraphic and electrocardiographic curves.

Interest in the method then lapsed until 1929, when Knox, of London, developed a kymographic apparatus utilizing the more powerful sources of x-ray at his command. Credit is due to Knox for having pointed out the possibility of the application of the method not only in cardiology, but in the study of the movement of the diaphragm, stomach, and colon.

Stumpf, in 1929, described a kymographic arrangement using multiple slits, thus obtaining records of the movement of many points of the heart simultaneously. He has applied this method to other organs beside the heart, as indicated by Knox.

the pulsatory motion direct and transmitted, of the pulmonic structures are recorded.

Comparison of the technic employed by various workers shows differences in the size of the slit, the speed of movement of the film, and the focal distance (Table I). The ideal arrangement would appear to be a very narrow slit, a high speed of film movement, and a long focal distance. But the smaller the slit, the faster the movement, the longer the distance, the greater would be the intensity of radiation necessary to make a satisfactory kymogram at a two-meter distance. Thus, with 0.4 mm. slits and 1.2 cm. per second film speed, it is necessary to energize the tube with 300 ma. at 100 K.V. over a period of one second for a distance of 200 centimeters. It is apparent, therefore, that at present technical limitations to the production of the ideal kymogram exist. The technic followed in this work is the closest approach to these conditions, considering present limitations in equipment.

TABLE I.—TECHNIC USED BY VARIOUS INVESTIGATORS

	Slit	Rate of film movement per second	Exposure	Equivalent exposures per second	Distance
Goett	3 mm.	6 cm.	3.5 sec.	6	50 cm.
Crane	2 mm.	5 cm.	1 sec.	25	60 cm.
Knox	2 mm.	5 cm.	8 sec.	3	(?)
Stenstrom and Westermark	1 mm.	2 cm.	2 sec.	10	75 cm.
Stumpf	2 mm.	5 cm.	2 sec.	12½	80 cm.
Stumpf	0.5 mm.	1.2 cm.	3 sec.	8	100 cm.
Hirsch	0.4 mm.	1.2 cm.	1 sec.	30	70 cm.

The apparatus constructed by the hospital physicist, Myron Schwarzschild, is of the multiple-slit type. It consists of an impervious plate with slits of equal width, a mechanism for moving a film at a constant speed behind a grid, a mechanism for energizing the x-ray tube shortly after this movement begins, and for cutting off the energization of the tube shortly before the film movement ends.

The arrangement is essentially a grid diaphragm mechanism with the springs removed. In place of the grid there is mounted a carriage to hold a 14 × 17 cassette. This is mounted vertically, so that, when released, the film falls by its own weight. On the front of the frame, between patient and film, there is mounted a lead grid consisting of slits 0.4 mm. wide, spaced at a distance of 12 mm. from each other. The grid-diaphragm contactors have been so rebuilt that the exposure can be adjusted by means of a speed control. A time marker record, in fifths of a second, is impressed on the film during its exposure.[3]

Since the width of the slits is only one-thirtieth of the distance traversed by the film while the exposure is being made, the set-up must be such as gives a perfect film in one-thirtieth of the actual exposure time. An exposure of at least one second is necessary to cover at least one cardiac cycle. Satisfactory kymograms may be made with 87 K.V. peak, 100 ma., at 70 cm. distance, for the average chest. The

[3] This consists of a small electro-magnet mounted on the back of the fiber sheet in such a way as not to interfere with the motion of the mechanism or cast a shadow. The armature of this electro-magnet is so extended as to project parallel to the edge of the film and near the edge. This extension casts a shadow on the film, and at every impulse produces a projection on the recorded shadow. It is connected through batteries to a contact which is operated by clock-work or synchronous motor to close five times a second.

The synchronous motor driving the time marker may be the same one which drives the time marker of the electrocardiograph, so adjusted that the marks on the x-ray film come simultaneously with the fifth second divisions on the electrocardiogram. In order to determine the heart beats in the electrocardiogram which are recorded by the x-ray, another electro-magnet of similar construction is mounted in front of the electrocardiographic camera and actuated by the voltage applied to the x-ray transformer primary. A mark will thus be left on the electrocardiogram, showing when x-rays started and stopped, thus serving the double purpose of orienting and checking the timing mechanism.

kymograms have excellent photographic quality, as a rule, due to the action of the grid as a partial "scattering absorber."

The kymograms in this study were all made with the subject in the standing or sitting position, in inspiration and with the slit placed horizontally. If desired, a film without intensifying screen may be placed outside of the grid so as to obtain simultaneously an ordinary roentgenogram of the chest (Fig. 1-*D*). The horizontal position of the slits cannot give absolutely accurate records of all the components of the complex cardiac motion, nevertheless it is suited for practical purposes because the main component of cardiac motion is the lateral thrust.

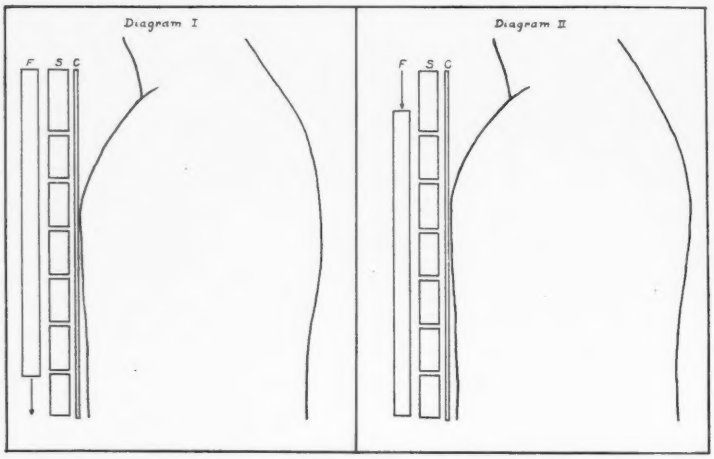


Fig. 1-*D*. *C*, control film: *S*, lead sheet with slits: *F*, cassette and film which move downward a distance slightly less than the distance between slits. Diag. I, before, and Diag. II, after movement of the film.

Description of the Kymogram.—The kymogram differs from the ordinary roentgenogram in the following details (Fig. 2):

1. It is crossed by regularly spaced white lines dividing the film into a series of bars.

2. The entire contour of the median shadow shows a definite wave in each bar which crosses it. The wave is a record of the movement of a particular point of the structures shown in profile in the median shadow. The form of the wave differs over different parts of the cardiac silhouette and is related to the chamber forming the contour.

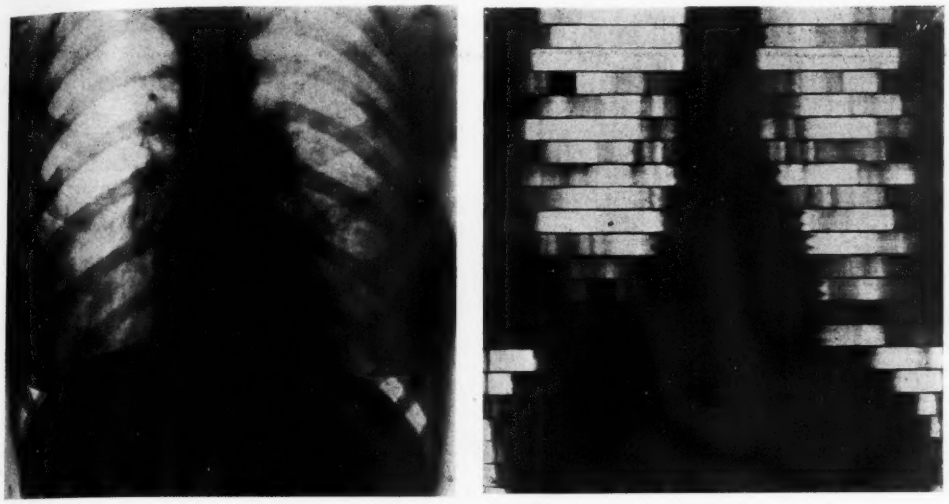
3. The cardiac shadow is no longer of homogeneous density but within each bar there are zones of varying density, representing a gradual transition from light to dark. These zones are the record of the variations of the actual density of the heart in diastole and systole. The exact extent of this change in density has been measured by Stumpf with a densograph.

4. The usual pulmonic markings are shown as wavy lines.

5. The ribs are not discernible as such, and the peripheral contours of the pulmonic field consist of a series of vertical lines.

6. The diaphragmatic curves are replaced by bands in a step-like formation.

1. The white lines represent the edges of the impervious plate at the slits and are visible because the film moves just short of the distance between two slits. If it moved the entire distance, there would not be any such linear shadow but the waves would overlap—an undesirable condition. These white lines divide the pulmonic field



Figs. 2-*A* and 2-*B*. An ordinary roentgenogram of the heart (Fig. 2-*A*), and a typical roentgen-kymogram of the same heart (Fig. 2-*B*). The waves over the entire cardiac shadow are movement records of the particular portions of the heart. These points are close enough together to give an accurate representation of the general contour. Waves of different shape and size may be distinguished over different portions of the heart contour, due to a variation both in the time and amplitude of movement of the various chambers. The peak of the wave represents the particular portion of the heart in maximum diastole, and the deepest points of the valleys represent the position of the particular chambers of the heart in maximum systole. Since the film moves downward, the diastole is the proximal leg and the systole, the distal leg. The difference in the form and size of the ventricular, auricular, and aortic waves is striking. Even in a normal heart the ventricular movement imposes its movement on the auricles, so that peaks ventricular in character are seen over the adjacent portion of the auricles, in addition to the characteristic auricular waves. At the junction point between ventricle and auricle, auricle and aorta, and auricle and pulmonary artery, waves characteristic of both chambers may be observed. Since the exposure is 1 second, the distance between the black lines may be divided off into as many portions as is desired, representing fractions of a second. By laying off on the waves of each bar a definite distance, corresponding to a certain fraction of a second, and connecting these homologous points, the shape and outline of the entire heart at that particular instant may be shown.

and cardiac shadow into a series of bars. These bars do not show homogeneous illumination. At the periphery of the pulmonic fields some, for a varying distance, show no illumination over areas corresponding to the position of the ribs.

2. If the contour of a structure has no movement or has movement absolutely parallel to the contour edge, the edge of the shadow is a vertical line. If the contour has movement and this is at an angle to the contour edge, this movement is shown as a wave. The kymographic wave permits analysis as regards form, amplitude, duration, and phase or time relationships.

Form.—The form of the wave with a definite rate of film motion depends on the character of the movement of the particular point of the heart. A very sharp peaked wave is produced by an extremely rapid movement and change in direction. The movement may be so fast that its record is practically a horizontal line. A dome-like wave represents a slow change in direction, a progressive increase and diminution in the speed of movement—a motion similar to that of a swinging pendulum (Fig. 9-*C*). When the to-and-fro motion is not regular, the motion being faster in one direction, the faster motion produces a straightening and shortening of the particular leg of the wave (Fig. 9-*B*). The legs of the waves may be straight or curved depending on the speed of motion. Imposed on these waves are angulations, hooks, peaks, indentations, and terraces, representing the rapid changes in the direction of the movement of the cardiac muscle, movements of the heart as a whole, and local vibrations produced by currents of blood within the heart (Fig. 9, a′, b′, c′, d). The study of the wave thus gives in-

formation as to the speed, regularity, and direction of movement.

In the analysis of the significance and meaning of the waves it is obvious that the outward thrust of the heart action (diastole) produces one side of the wave and the inward thrust (systole), the other. The crest of the wave represents the end of diastolic period or beginning of systolic, while the deepest portion of the trough represents the period of maximum systole or the beginning of diastole. Since in the kymographic apparatus here utilized the film moves downward, it is the proximal

Fig. 3. Normal kymogram of an asthenic individual with vertically placed heart. From Bar 12 to Bar 17 the waves are those characteristic of the aorta. In Bar 12 the wave is purely pulmonic; Bar 11 shows the evidence of auricular motion; in Bar 10, the wave is purely auricular; in Bar 9, the wave begins to show ventricular characteristics such as are found over the remaining left border. Note that the apex of the wave approaches closer to the upper edge of the bar as one proceeds down the left border, indicating a sort of peristalsis of ventricular wall. The small notch on the diastolic limb in Bars 3, 4, 5, and 6 corresponds to the second sound and the serration at the peak of the wave corresponds to the first sound. The right contour of Bars 3, 4, and 5 shows definite ventricular motion (right ventricle). In the two bars above this the waves are both auricular and ventricular, and in the next bar above this they are purely auricular. The boundary of the particular chamber is that point where the ventricular wave gives way to a mixed wave.

side which is diastolic and the distal, systolic in origin, and the record is to be read from below upward.

Amplitude.—The change of position of any point is fully and completely registered when its movement lies parallel to the direction of the slit. If the movement is not a simple one, but complex and in a changing direction, only those components of the movement will be completely and accurately recorded which are in a direction parallel to the slit. It is important to bear this in mind since it serves to explain the waves of exaggerated amplitude occasionally to be demonstrated, particularly over the apical portion of the heart. In such cases, sharp, clear, and standard waves may be obtained by a change in the position of the grid so that the slits run at an angle to the vertical axis of the chest. When the motion is exactly parallel to the direction of the slit, the amplitudes of the waves may be measured by the ordinate.

If the motion is not parallel to the direction of the slits, as is the case with the greater portion of the left cardiac border, particularly in cases in which the upper part of the contour runs obliquely to the direction of the slits, the amplitude may be determined by projecting corresponding peaks and troughs of two bars to the horizontal line bounding each bar and connecting these projections. The perpendicular distance between these lines is the amplitude. The measurement, however, does not indicate the exact amplitude of movement, for, with a focal distance of 70 cm., there is some magnification.

While the shorter focal distance prevents teleroentgenographic measurements, it nevertheless has the advantage of emphasizing by slight magnification the more delicate and less perceptible portions of a wave.

Duration.—The duration of the wave (abscissa) depends on the frequency of the movement of the part and the speed of movement of the film. It is measured between two homologous points of the waves, either between two troughs or two peaks. The speed of the film movement being constant and known, the actual duration of the wave may be easily determined. This estimation is simplified by checking the interval periods against the record of the time marker. The number of waves within the bar (between two white lines—frequency) varies directly with the rapidity of the heart chamber contraction.

The greater contraction-frequency, the more compressed the wave; the less frequency, the more extended and flatter the wave. For comparison of the waves it is necessary to take the rate into consideration.

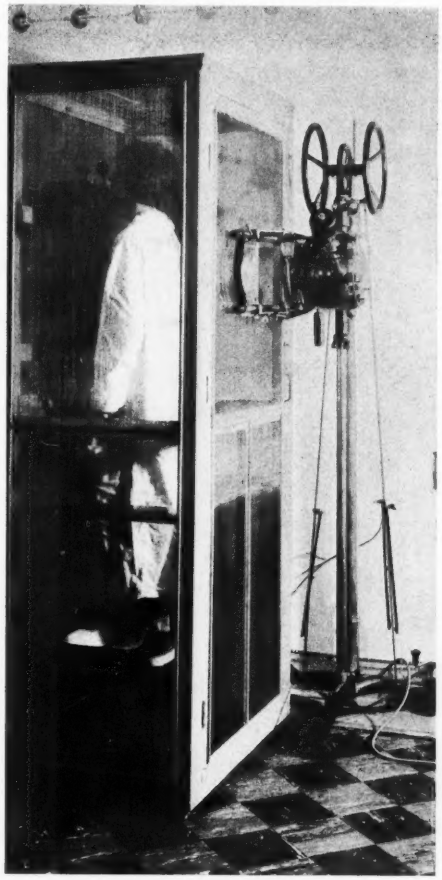


Fig. 4. Showing a patient in position for combined electrocardiographic and roentgenkymographic examination. The cage is essential for the production of undeviated E.K.G. waves.

Phase or Time Relationship.—To compare the time relationship of the various points of the waves—the distance from a fixed point—the upper or lower line of a bar is used. The distance of a certain point on the wave from this line is measured with calipers and laid off from a corresponding fixed point on the wave of any particular portion of the cardiac shadow. In this way it may be determined whether the waves compared are ventricular, auricular, or vascular in origin. It is by this method that the components of the composite waves over certain portions of the contour are isolated and the origin of the waves in the cardiac or pulmonary shadows determined.

On comparing the time relationships of all the ventricular waves traced by the left border of the heart, there is to be observed a progressive advance of the point of onset of each wave, as if a migration of the wave had occurred. In other words, the visible evidence of ventricular systole appears earliest at the base and progresses downward, appearing last at the apex of the heart. The difference in time observed is about 0.05 second. The phenomenon is general, but varies under normal and pathologic conditions.

The analysis of the kymographic wave thus gives the character, direction, speed, and regularity of the movement of any particular part of the heart, and this depends upon the excitation phenomena, the mass (thickness), and elasticity (tonus) of the contracting muscle, and upon the nature of the surrounding tissue.[6]

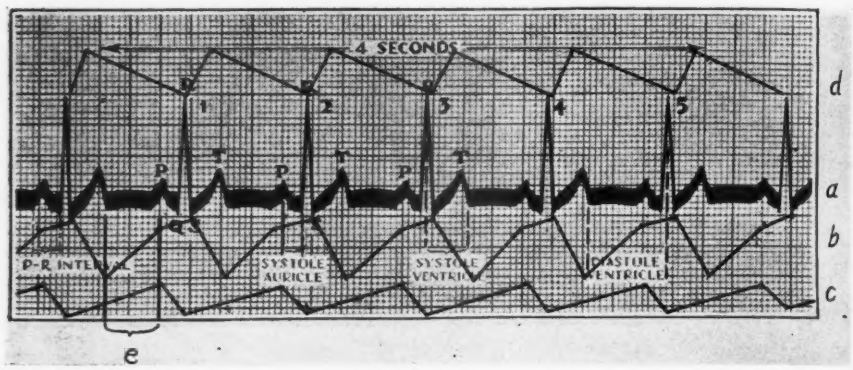


Fig. 5. Diagram showing the relationship of the roentgen-kymogram to the E.K.G. record, made simultaneously: (*b*) represents the ventricular waves; (*d*) the aortic waves, and (*c*) the auricular waves. A comparison of the E.K.G. and kymographic waves shows that the beginning of the Q-R-S wave precedes the beginning of systole by about 0.09. The P wave corresponds to the break in the diastolic limb of the ventricular wave, and the T wave corresponds to the end of systole. The maximum outward thrust of the aorta is attained early in ventricular systole. The heart is in complete diastole during the period marked (*e*).

3. The photographic density of the heart shadow in the various bars is not homogeneous but consists of zones, or lighter and darker bands[7] corresponding exactly to the diastolic and systolic phases. The white zone (unilluminated) is a record of the density of the heart in diastole; the dark (illuminated) zone is a record of the decreased density in the anteroposterior diameter of the heart in systole. All pulsating structures show these density bands. These density changes are particularly marked in the region of the apex.

[6] The lungs appear to exert a dampening or cushion effect on the heart motions. Thus in a pneumothorax with retraction of the lung, the motions are exaggerated, the waves showing increased amplitude, while in the presence of pleural effusions or pulmonary consolidations the movements are of diminished amplitude.

[7] Irregularities in the movement of the film may produce horizontal lines in the frames. These, however, extend beyond the cardiac border and are very sharp and clear-cut.

4. The waves outside the heart border, in the pulmonic fields, are produced by the movement of the pulmonary vessels. Pulmonary waves are classified as primary and secondary: the primary are the result of intrinsic vascular motion; the secondary of transmitted motion. These waves vary in size and extent in different portions of the pulmonic field, being most distinct normally opposite the pulmonary conus, the ascending aorta, and at the base.

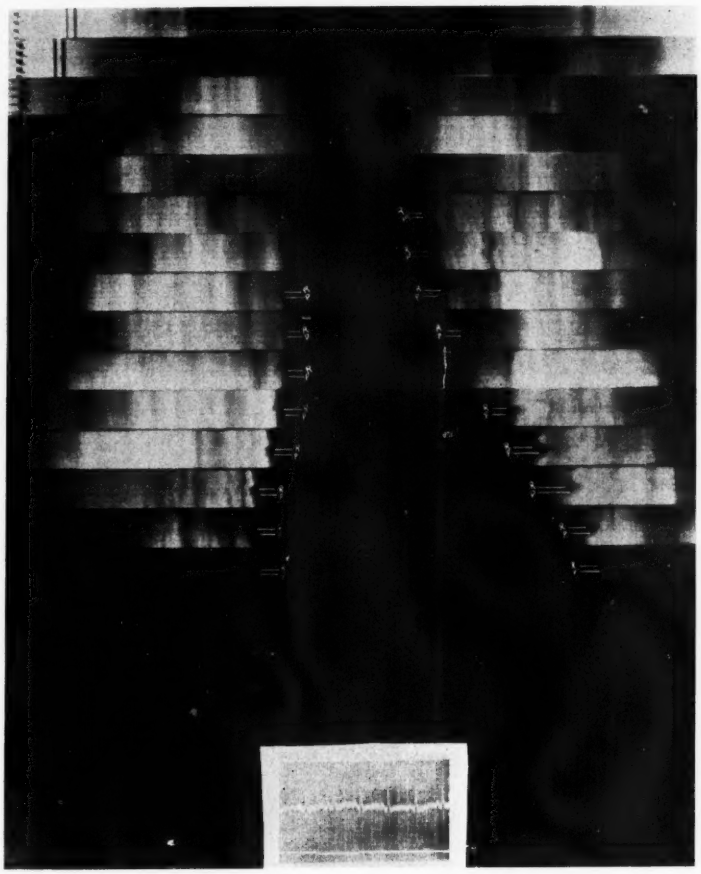


Fig. 6. Roentgen-kymogram showing the simultaneously made E.K.G. record. Note the absence of any distortion of the E.K.G. record. The exposure took place over the period indicated by the heavy line under the E.K.G. waves. The relative positions of the peaks of the R and P waves are indicated on the kymographic waves. In the upper left-hand corner are time marker divisions indicating fifths of a second.

The vascular waves have all the same phase and periodicity. The waves of the pulmonary markings have greater photographic density, the nearer they are to the median shadow. The presence of immobile shadows in juxtaposition to actively moving ones, must be discounted as being the shadows of projected distant structures. The study of the waves in the pulmonic field is important as indicating the distribution, size, number, and structure of the pulmonary vessels. Prominent vascular waves which do not decrease in ampli-

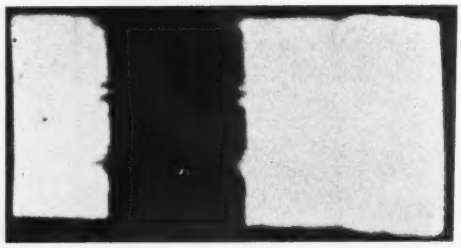


Fig. 7. Sound record of the heart enlarged. The band represents the shadow of the lead strip moved by the oscillograph. The shadow of the lead strip has straight edges except at those points where it is moved by the heart sounds. The second sound is split in this record.

tude as they extend toward the periphery indicate change in the vessel, its content (congestion), or a change in the elasticity of the pulmonary parenchyma. Transmitted motion is differentiated from intrinsic pulsatory motion by the presence of changes in the photographic density in the latter.

5. The ribs show as band-like rectangular shadows which jut into the pulmonic field. The shadow is most dense at the periphery of the pulmonic field which now is bordered by a series of rectangular shadows with relatively illuminated centers, which corresponds to the cortex and medulla of the ribs. If necessary, the actual position of the rib shadows may be reconstructed from these rectangles.

6. The smooth convex contour of the diaphragm is broken up into a series of steps—shortest at the center of the dome and longer toward the costophrenic spaces. The actual position of the domes may be obtained by connecting homologous points on these step-like shadows.

Characteristic curves are found for the different portions of the cardiac contour which are related to the chamber responsible for the contour.

Ventricular Waves.—These waves consist fundamentally of a sharp smooth inward limb representing systole, followed by a bent limb representing diastole. Two components are distinguishable in the diastolic limb—an acutely rising portion which is followed by a more gradual rise to the point of maximum dilatation. This is cut abruptly by the beginning of the next systole. There is apparently no pause in the cardiac movement: the so-called diastolic rest period does not appear normally.

Imposed on the limbs of the waves are notches, indentations, and low sharp peaks. These represent vibrations, some of which correspond in time to the first sound of the heart and are, therefore, due to movement phenomena associated with it, while some represent movement imposed on the ventricle by other chambers and some, the movement of the heart as a whole.

The curve is not, therefore, merely a simple volume curve of the ventricle, but a rather complex tracing of the movements of the heart, both those due to actual muscular contraction of the individual chambers and of the heart as a whole.

The waves observed over the left ventricle are characteristic, though they vary somewhat in form. The simple angular form is most commonly found in a small segment of the upper part of the ventricular contour, while the remaining portion of the ventricle shows the trapezoid or rounded form. As the apex is approached the rounded form appears. In adults, in the aged, and in hypertrophied hearts, the apex may show practically no waves, indicating a diminution or absence of lateral motion.

The wave of the right ventricle is of the same type as that of the left ventricle. The duration and amplitude of the systolic portion of the wave is the same as that of the left ventricle. The diastolic phase may differ slightly from that of the left ventricular wave in a delay of two-fifteenths of a second. This may be due to the superposition on the ventricular waves of motion of the heart as a whole.

Ventricular waves are found over the left cardiac contour, beginning at a point just below the left auricular bulge and extending over the entire left lower border, around the apex. They are also visible on the lower third or half of the right cardiac border. This would indicate that the lower part of the right contour, as well as

the entire inferior border, is definitely right ventricle in all individuals. The waves over the upper part of the right contour are associated with auricular motion (Fig. 3).

The study of the structure of the ventricular waves would indicate that the diastolic ventricular enlargement takes place rapidly at first, then slowly. The primary outward thrust is due to rapid ventricular filling before active auricular contraction, and the second, slower segment, beyond the point of angulation, is due to the final action of the auricular contraction. The major part of ventricular filling seems to take place shortly after the ventricle goes into relaxation, and is in large part completed before the subsequent auricular systole, which begins at the point corresponding to the break in the diastolic limb of the ventricle. In the latter part of the diastole the blood enters the ventricle slowly, the length of this period depending on the duration of the entire cycle. If the heart rate is rapid, this period is shortened or absent. The systole of the auricle apparently plays but a minor rôle in adding blood to the ventricles. This break in the contour of the diastolic limb always occupies relatively the same position normally, but shows considerable variation in lesions in which there has been interference with the auricular contraction.

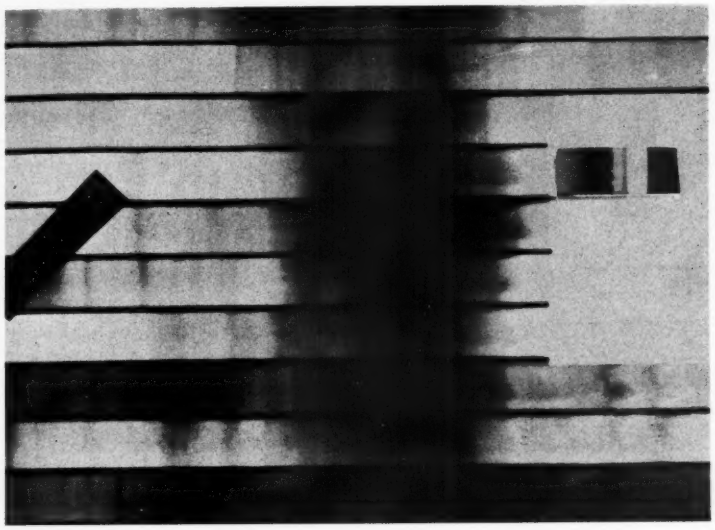


Fig. 8-*A*. The sound record of this case is placed in the aortic area of the kymogram. The second sound (middle peak of sound record) corresponds to a notch on the retracting limb of the aortic wave, a short distance after its beginning. The notch is due to vibrations produced by the current of blood arising from the closure of the aortic valves. An exactly similar condition is found in the pulmonary artery.

Auricular Waves.—The waves of the auricles are characterized by a simpler structure and a smaller amplitude than the ventricular waves because the auricles do not have as vigorous motion as do the ventricles. The pure auricular wave consists of a low, slowly ascending limb (diastolic) and a relatively short rapid limb (systolic). Undefiled auricular waves, however, can be made out only over a small portion of the upper part of the left and right auricles.

The time relationship to the ventricles is such that the peak of the ventricular wave corresponds to the deepest valley of the auricular wave. However, over the major part of the contour of the auricles, the dominant ventricular contraction imposes its own characteristic waves and the resultant wave is a composite of both.

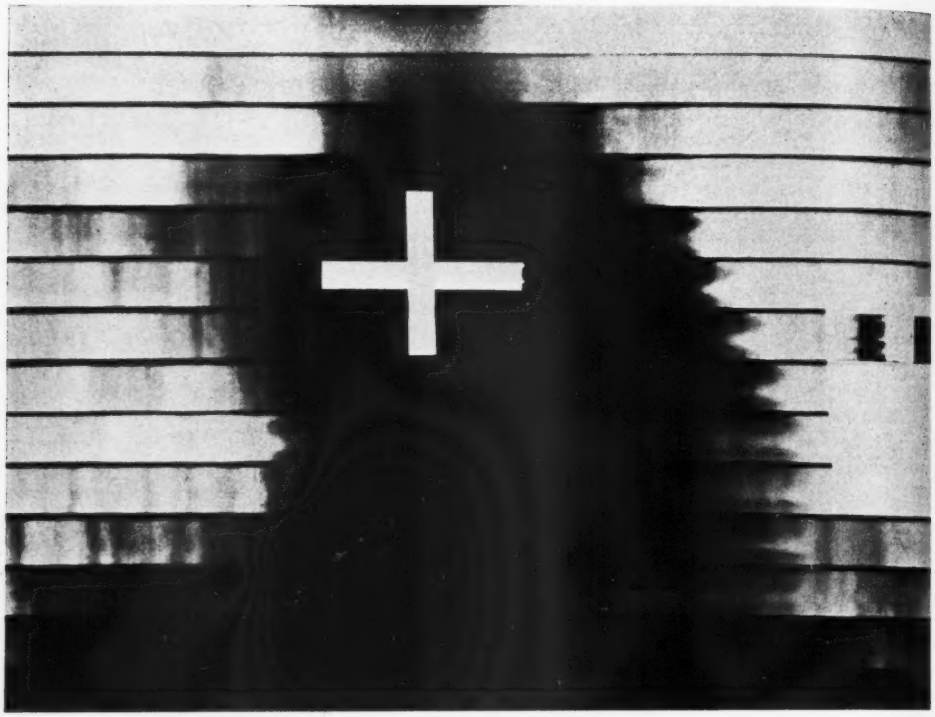


Fig. 8-*B*. In this case the sound record is placed opposite the ventricular area for correlation with the ventricular waves. The lowest and uppermost peaks of the sound record (first sound) correspond exactly to a definite notch on the systolic limb of the ventricular wave, a short period after the beginning of systole. The sound vibration is completed long before systole is finished. It would thus indicate that the first sound is accompanied by a very rapid vibration of the ventricular wall. An exactly similar condition is found in the right ventricular waves. The cross indicates the position of the stethoscope.

The complicating ventricular wave interposed between the auricular waves may exceed the auricular waves in amplitude in portions of the auricles closest to the ventricles. At the transition points between the chambers the waves of motion have always a more or less composite makeup.

Vascular Waves.—There is a striking similarity between the pulmonary artery and aortic waves, with the difference that the peak of the aortic wave is sharp while that of the pulmonary artery is blunted or flattened. The amplitudes of the pulmonic waves are less than the aortic.

The wave produced by the aorta consists, normally, of a slow, long, descending limb (inward movement) and a sharp, steep, almost horizontal outward thrust. The point of maximum outward thrust is attained before the completion of the ventricular systole. These waves are usually definite and clear over the entire aortic shadow. Over the ascending arch shadow, they may be complicated by a flat wave, due to motion of the superior vena cava. These are characterized by a slow rise, a serrated or domed peak, and a slow descent. In reality the dome consists of three short peaks. These are the auricular, venous and a peak which corresponds to the C wave of the pulse waves. The waves of the thoracic aorta may normally be observed through the cardiac shadow along the left side of the spine, as far as the diaphragmatic zone.

The sharp rise of the steep ascending limb of the aortic wave begins simultaneously with the beginning of the ventricular

systole. The peak of the wave is attained just after the beginning of ventricular systole. From this peak the wave shows, at first, a rapid descent, broken by a notch and then a slow descent. The notching is due to phenomena associated with the closure of the semilunar valve (Fig. 8-*A*).

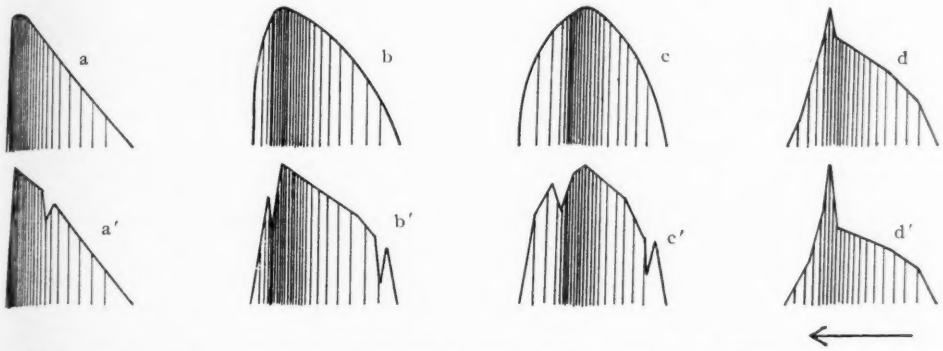


Fig. 9. Diagrammatic representation of the various types of waves and the vibrations imposed on them by the phenomena which produce the heart sounds.

At the summit of the arch of the aorta, the waves may be seen within the mediastinal shadow. From this point downward the waves in the contour of the mediastinal shadow become more distinct and clearly defined, since they are contrasted against the background of the pulmonic fields. Under normal conditions the waves on the left side of the aortic shadow are more prominent than those on the right side, but in increased heart action the shadows on the right side may exceed those on the left in sharpness, distinctness, and prominence. The heart size appears to bear no direct relationship to the amplitude of the aortic waves.

In the examination of the same individual at different times under unchanged conditions, no significant variation in the characteristics of the waves (shape, amplitude, and distribution) for the particular individual has been found. In other words, the particular type of heart action is characteristic for the individual. Though posture modifies the heart shape and size slightly, the changes in the wave forms are insignificant.

For comparison, kymograms taken at rest should be compared with others taken only at rest, and those taken during exercise with others taken under the same conditions. Exercise which increases the frequency and the amplitudes of the waves does not, however, change the characteristics, and it also increases the migration of the wave and the upward movement at the apex.

It is important also that the kymograms be made in a standard posture and during a definite respiratory phase, preferably in deepest inspiration. This is particularly necessary, for not only does the general heart form differ in expiration and inspiration, but the kymographic waves differ in their number, form, and amplitude. Thus portions of the cardiac shadow which show insignificant waves during inspiration, will during expiration, show strongly marked waves. Over the ventricles, the sharp-pointed elements in inspiration give way to the rounded elements in expiration. The right contour of the vascular shadow may show insignificant waves during inspiration, but during expiration definite high sharp-pointed waves appear. In expiration, the waves over the left contour of the aorta have a markedly increased altitude.

Analysis of Contours.—In a kymographic examination, each chamber of the heart, as well as the aorta and its great vessels, writes on the film a wave with the features sufficiently characteristic to permit the determination of the exact part they play in

the formation of the heart silhouette. Further, the transition points between the various contours may be placed with greater accuracy than is possible in the ordinary roentgenogram.

Kymographic studies indicate that it is necessary to revise our ideas regarding the component elements of the cardiac contours. In the ordinary roentgenogram of a normal heart, the right cardiac contour in most instances under normal conditions appears to be a simple continuous curve. The kymogram permits the division of this contour into two and in certain hearts into three parts—one formed by the right ventricle, one by the right auricle, and one by the left auricle. That formed by the right ventricle lies just above the diaphragm and occupies the lower third or half of the right cardiac shadow; the central portion is formed by the right auricle, and the uppermost segment in vertical hearts by the left auricle.

From the kymogram it becomes possible to determine the shape and size of the heart at any phase of its movement cycle. This is accomplished by laying off on every wave the same time value and connecting these points. Thus a series of tracings may be obtained, giving the heart shape at any particular instant from maximum systole to diastole, either of the ventricles or auricles. Such a serial analysis may be helpful in doubtful cases in differentiating normal from pathologic heart shapes.

The determination of the boundary or transition points between auricle and ventricle, auricle and pulmonary artery, or auricle and aorta may be best determined by means of caliber measurement of certain points, notably maximum diastole and maximum systole from the fixed points (bar lines). If in two neighboring bars, the maximum diastole of one wave corresponds in point of time to maximum systole of the other, the transition point is located on the line between the two bars. This method permits the more accurate measurement of the cardiac shadow. Since the boundary between the various chambers and the points of maximum and minimum deviation may now be determined with accuracy, the placement of the points utilized for the measurements of the cardiac diameters becomes more precise, and the gross inaccuracies of the present-day methods of roentgenographic cardiac measurements may now be corrected.

Study of the silhouettes of the heart during systole and diastole of the ventricles shows that when the ordinary standard measurements are applied there is a considerable difference in the values of the standard diameters, the transverse, long and broad, depending on the particular phases of movement depicted. The difference is particularly marked in the broad and transverse diameters, where the amplitude of the kymographic wave may be as much as 20 per cent of the left transverse diameter. A transverse measurement, as taken from the ordinary roentgenogram, may err to the extent of over two centimeters, depending upon the particular phase of contraction in which the heart is depicted.

The method permits the analysis of cardiac movement. With a series of contours of the cardiac outline in various phases of its activity, it is possible to study the extent and direction of the movement of the various portions of the heart as well as that of the heart as a whole. A polygraphic tracing demonstrates this graphically.

Correlation with Electrocardiography.—From the beginning of kymoroentgenographic studies, the correlation of the waves to sphygmographic and electrocardiographic records has been attempted.

Goett, in 1917, described kymographic curves obtained from the left ventricle, the right auricle, and the aorta, and synchronized these curves with radial pulse tracings. The sphygmographic tracing is, however, of little help because the exact time of the radial pulsation in relation to the heart cycle is not a fixed one.

In 1912, Theodor and Franz Groedel published the results of studies linking the electrocardiograph with the actual changes in heart contour as roentgenographically recorded. By means of a rapid plate

Fig. 10. Roentgen-kymograph with simultaneous roentgenphonogram. By putting a straight edge on the sound record the relationship of the first and second sounds to the movement record may be determined. It will be seen that there is a peak on the systolic limb of the ventricular wave which corresponds to the first sound and another peak on the beginning of the diastolic limb corresponding to the second sound.

changer, twenty-four exposures of the chest were made in succession. With the E.K.G. electrodes on the patient, the making of an x-ray exposure resulted in the loss of an E.K.G. string. By changing the magnets to permanent magnets, and placing condensers in the E.K.G. circuit, they succeeded in preserving their string, but at each exposure the record showed a blank space.

They also found a drift of the string, so that at the end of six exposures, the process had to be interrupted and the string brought back on to the film. From the series they obtained a set of chest roentgenograms, each one having a definite relation to the E.K.G. cycle, determined by the corresponding break in the E.K.G. record.

Knox made comparative studies of kymogram waves and electrocardiograms, but did not synchronize them.

In 1913, Becker reported work similar to that of the Groedels. Becker's contribution to the problem lies in his having applied the kymographic principle practically and also in the successful application of the simultaneous E.K.G. record. His method of eliminating the x-ray interference with the E.K.G. consisted in applying the Groedels' method of minimizing the

effect and adding a foil screen between patient and x-ray tube.

Stenstrom and Westermark attempted to solve this problem by the use of compensators to induce into the E.K.G. circuit additional disturbances, out of phase but of the same frequency as the undesired disturbances. Because of destructive interference it was hoped that an undistorted record would be obtained. These expectations were only imperfectly realized, however, as the E.K.G. records of these investigators show decided irregularities during the time the x-ray tube was energized. Their compensator method is too complicated for application to routine laboratory use, involving, as it does, careful adjustment and preliminary test films for each case, since the slight disturbances can be detected only after the development of the E.K.G. film.

Schwarzschild, working in our laboratory, found that, broadly speaking, there are two kinds of interference with the E.K.G. The high voltage, pulsating D.C. actuates the x-ray tube which leaks into the string circuit and causes the galvanometer string to move and stay out of the field, as long as the x-ray tube is energized. This effect he attributes to a static charge, and the experience of the Groedels verifies this hypothesis. Electrostatic shielding of the galvanometer string circuit from the high tension circuit overcomes this difficulty, but there remains, as Stenstrom and Westermark also found, a 60-cycle fluctuation which cannot be attributed to the high tension circuit, since its fluctuations, in a fully rectified system such as was used in our work, have a frequency of 120 per second. The cause of these fluctuations must be sought at points in the system having a 60-cycle frequency, which fact excludes the high tension completely and leaves the low tension A.C. as the only possible source. It was found that a single wire connected to the live side of the 110-volt A.C. house circuit and brought to the vicinity of the E.K.G. circuit, caused violent vibration in the string, even though no current flowed through the wire. These fluctuations are, manifestly, not magnetic in nature, but electrostatic. It seems necessary, therefore, to eliminate completely all disturbances by electrostatic shielding from low tension as well as from high tension.

In order to carry out such a shielding arrangement, the electrocardiograph was set up in a room with lead-lined walls across a corridor from the x-ray tube and the high tension machinery. The E.K.G. electrodes and the kymographic apparatus were enclosed in a metal booth equipped with an aluminum window outside of which the x-ray tube was supported (Fig. 4). The E.K.G. leads were led out of the booth in a shielded cable to a shielded conduit crossing a corridor to a lead-lined room in which the string galvanometer was set up. An automatic method of compensation was used with the string galvanometer, consisting of a condenser of 100 microfarads in series with the string. The distortions introduced in the electrocardiograph by this method of compensation have no effect on time relationships and so do not weaken the strength of any of the conclusions.

The synchronization of the E.K.G. and the kymogram is accomplished by means of a pair of magnetic markers, one attached to the kymograph and so arranged that at each electrical impulse a trace of the stroke of the armature is left on the film, showing as a comb-like shadow in the upper right corner of the pulmonic field. The impulses are given to this marker by means of a contact mounted on the E.K.G. time-marker, so that at every fifth-second line of the E.K.G., an impulse is transmitted and one of the projections is produced on the kymogram (Fig. 6). The other marker is mounted in front of the E.K.G. camera and connected by means of shielded cable to a step-down transformer, the primary of which is shunted across the primary of the x-ray transformer. Thus during the period of the exposure, the trace of this marker shows a plateau-like projection on the electrocardiogram. By means of these markers, it is thus possible to correlate within 0.03 second any point in the E.K.G. with

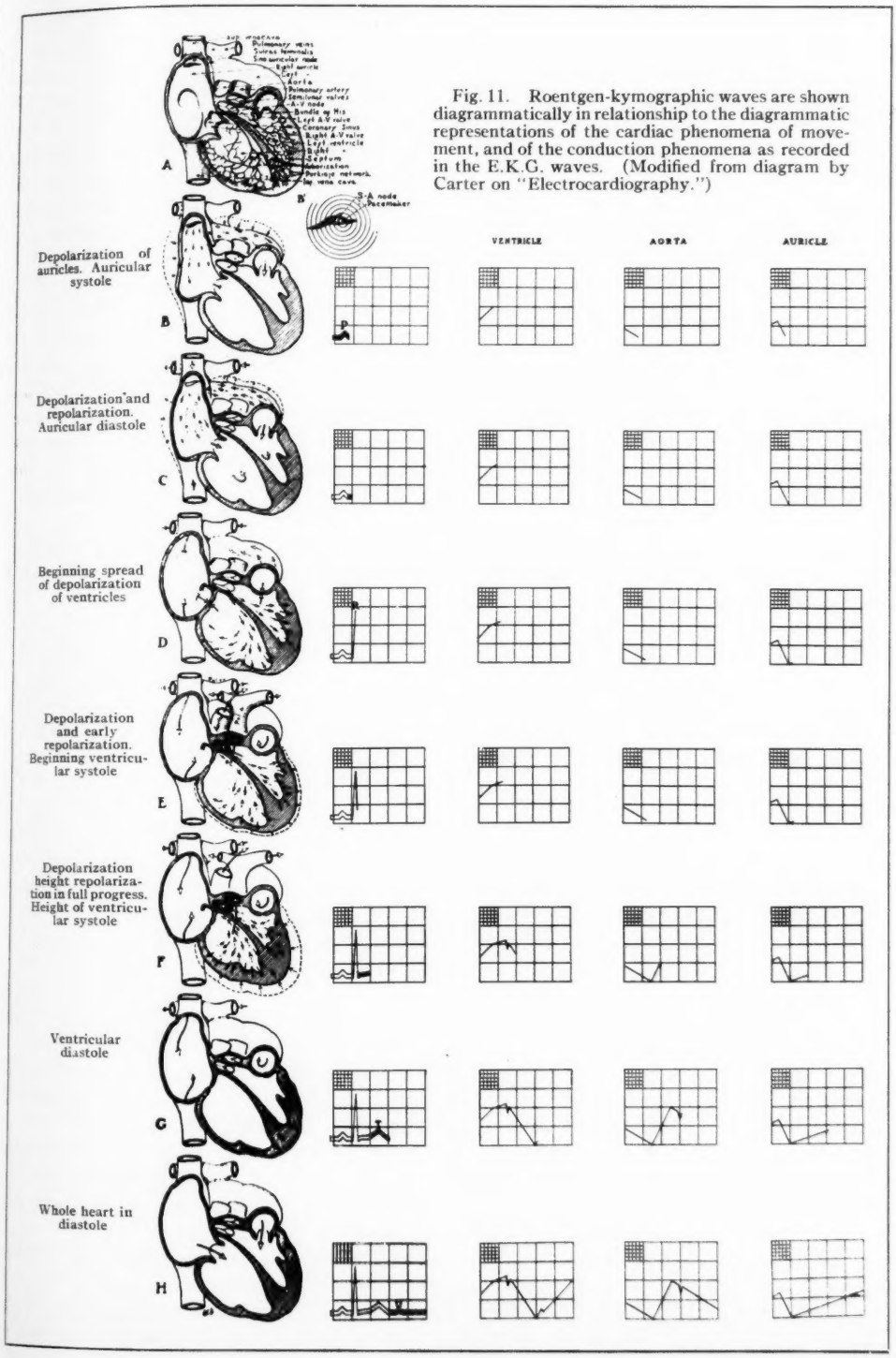


Fig. 11. Roentgen-kymographic waves are shown diagrammatically in relationship to the diagrammatic representations of the cardiac phenomena of movement, and of the conduction phenomena as recorded in the E.K.G. waves. (Modified from diagram by Carter on "Electrocardiography.")

the corresponding point in the kymogram. In making the simultaneous records the operator of the string galvanometer is in telephonic touch with the x-ray technician. The patient is fully instructed and, if necessary, rehearsed, as to the course of events. Then the string galvanometer is adjusted, and upon a signal, the x-ray technician is informed that all is ready as far as the E.K.G. is concerned. He, therefore, orders the patient to hold his breath and sets the film in the kymographic apparatus in motion by means of a magnetic release. The E.K.G. camera is started at the same time and the two records are thus taken simultaneously. The entire operation consumes only a few minutes and yields a synchronized electrocardiogram and roentgen kymogram (Fig. 6).

Correlation (Fig. 11).—The P wave is the auricular deflection, occupies presystole, and represents the spread of the electrical excitation-action current through the auricular musculature. The P wave is not more than 0.1 second wide and usually represents only about one-third of the duration of auricular systole. In the kymogram, the change in slope of the ventricular diastolic wave corresponds to the peak of the P wave. This change in slope or break in the diastolic wave of the kymogram is not due, as some believe, to the rotation of the heart in the process of relaxation after having been actively rotated in the opposite direction during systole.

The Q-R-S complex is the wave of ventricular excitation. It is due to an impulse which has traversed the A-V bundle; its main divisions, the right and left bundle branches, and arborizations, form the Purkinje network. In the kymogram, the point of the wave which represents the beginning of ventricular systole begins on the average 0.09 second after the beginning of the Q-R-S wave and may occur as late as 0.13 second after it.

The T wave represents the finale of ventricular systole and terminates when all parts of the ventricles first become quiescent. It represents the process of relaxation of the heart, the decline or subsidence of the state of electrical excitability in the ventricular musculature. In other words, it represents the stage of retreat of this electrical activity, as contrasted with the stage of invasion which gives rise to the Q-R-S wave. It has a maximum duration of 0.25 second. The deepest point of the kymographic wave (end of ventricular systole and beginning ventricular filling) corresponds to the end of the T wave.

The variations from the average in the relationship between the R wave and the beginning of the systole which were observed were within 0.04 second, and the variations from the average of the time relationship of the end of the T wave from the maximum systolic position were also rarely more than 0.04 second. The time measurements on the kymogram bear an inherent experimental error of the order of 0.03 second, due to slit width. It may, therefore, be considered that the above relations are exact within this experimental error.

Correlation with Heart Sounds.—Heart sounds have been roentgenographically recorded simultaneously with the kymogram by the following method:

A cassette containing a small x-ray film and screen is arranged to slip into a carrier firmly attached to the film carriage of the kymograph. In front of this cassette there is a lead plate with a slit. Between slit and x-ray tube there is an oscillographic unit, consisting essentially of an arm carrying a small piece of lead and capable of rotation around an axis. The rotation of the arm of the oscillograph is produced by a flow of current in an electro-magnet which attracts an armature rigidly mounted on the rotating member of the oscillograph.

Due to the relatively large inertia of the arm of the oscillograph and also to the fact that the slit must be reasonably wide in order to obtain a registration of movement during the x-ray exposure the oscillograph is actuated by currents of relatively low frequency.

The heart sounds are picked up from the chest wall by means of a stethoscope bell made of material transparent to the x-ray. The sounds are carried through a rubber

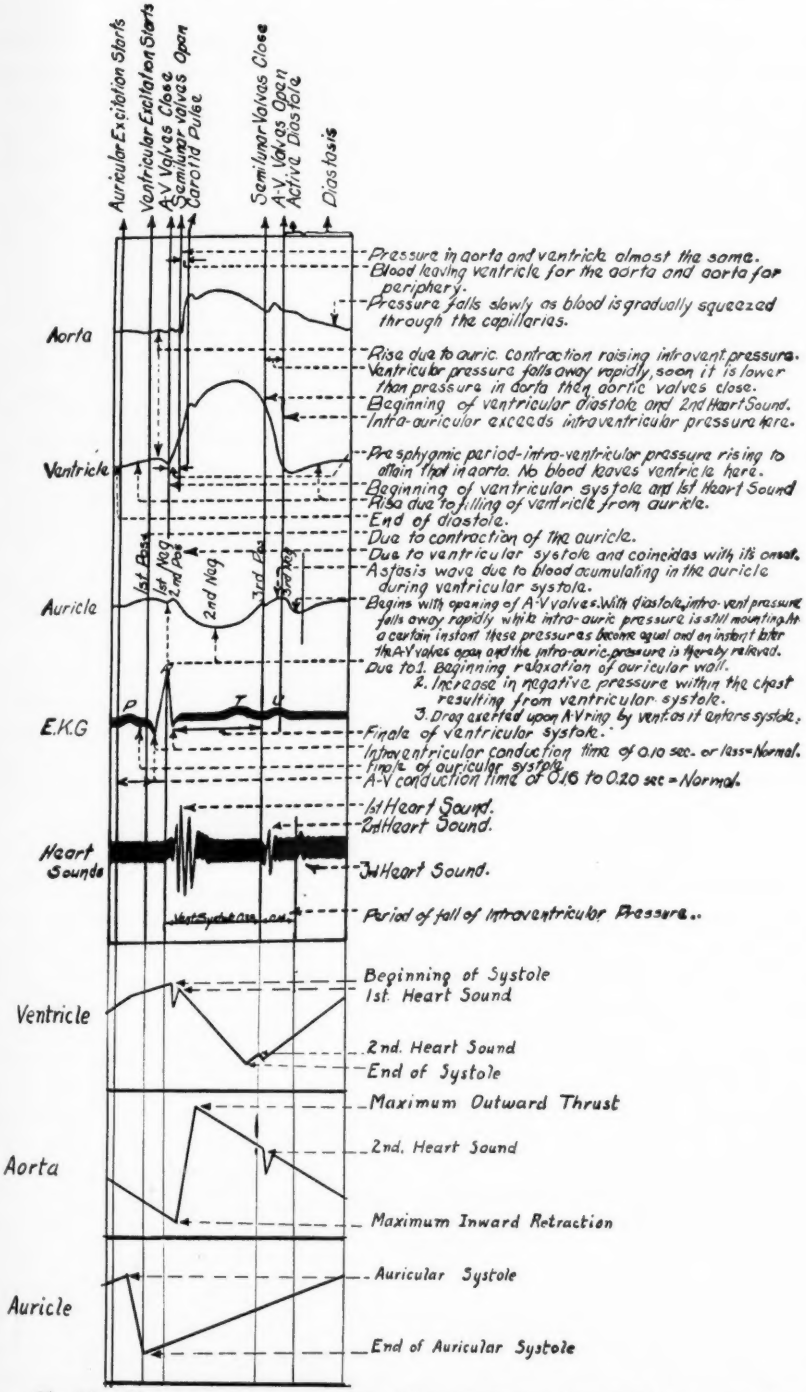

Auricular Excitation Starts
Ventricular Excitation Starts
A-V Valves Close
Semilunar Valves Open
Carotid Pulse
Semilunar Valves Close
A-V Valves Open
Active Diastole
Diastasis
Aorta
Ventricle
Auricle
E.K.G
Heart Sounds
1st Neg
2nd Neg
3rd Neg
1st Pos
2nd Pos
3rd Pos
P
T
U
Pressure in aorta and ventricle almost the same.
Blood leaving ventricle for the aorta and aorta for periphery.
Pressure falls slowly as blood is gradually squeezed through the capillaries.
Rise due to auric. contraction raising intravent. pressure.
Ventricular pressure falls away rapidly, soon it is lower than pressure in aorta then aortic valves close.
Beginning of ventricular diastole and 2nd Heart Sound.
Intra-auricular exceeds intraventricular pressure here.
Presphygmic period-intra-ventricular pressure rising to attain that in aorta. No blood leaves ventricle here.
Beginning of ventricular systole and 1st Heart Sound
Rise due to filling of ventricle from auricle.
End of diastole.
Due to contraction of the auricle.
Due to ventricular systole and coincidas with its onset.
Astasis wave due to blood acumulating in the auricle during ventricular systole.
Begins with opening of A-V valves. With diastole, intra-vent pressure falls away rapidly while intra-auric pressure is still mounting. At a certain instant these pressures become equal and an instant later the A-V valves open and the intra-auric. pressure is thereby relieved.
Due to 1. Beginning relaxation of auricular wall.
2. Increase in negative pressure within the chest resulting from ventricular systole.
3. Drag exerted upon A-V ring by ventricle as it enters systole.
Finale of ventricular systole.
Intraventricular conduction time of 0.10 sec. or less=Normal.
Fin/e of auricular systole
A-V conduction time of 0.16 to 0.20 sec = Normal.
1st Heart Sound.
2nd Heart Sound.
3rd Heart Sound.
Period of fall of Intraventricular Pressure..
Ventricle
Beginning of Systole
1st. Heart Sound
2nd. Heart Sound
End of Systole
Aorta
Maximum Outward Thrust
2nd. Heart Sound
Maximum Inward Retraction
Auricle
Auricular Systole
End of Auricular Systole

Fig. 12. Diagrammatic representation of the approximate time relations of the apical heart sounds, the pressure changes, the electrocardiogram, the roentgen-kymogram, and roentgen-phonogram phenomena in the right auricle, left ventricle, and aorta. (Modified from diagram by Carter on "Electrocardiography.")

tube into a microphone, the output of which is connected to a multistage vacuum tube amplifier. In this amplifier the heart sounds produce electric impulses corresponding to the frequency of the sounds. Because of their high frequency these impulses are not suitable for driving the oscillograph described above. In order to overcome this difficulty the output of the amplifier is led into a rectifying system and from there to the oscillograph. Thus the oscillograph unit is actuated not by the high frequency impulses of the sound itself but by a relatively slowly varying current which corresponds in contour to the intensity of the heart sound itself. At each sound the armature is attracted and the lead marker deflected in front of the slit, to return again at the end of that sound to its original position.

The developed small film shows a record of the movement of the lead marker. In the absence of sound the shadow of the marker is a straight bar with parallel sides, while with sound this shadow shows a notched edge. The depth of the notch is proportional to the intensity of the heart sound and the time duration of the notch corresponds to the duration of the heart sound (Fig. 7).

These shadow records have precisely the same time scale as the kymogram with which they are made because the film for the sound record and kymogram film move together and the exposure of both films is made by the same x-ray beam under the same conditions of excitation.

These sound records may be placed alongside any bar of the kymogram and the relationship of the heart sound and the phenomena depicted in the kymogram may be directly observed, or the waves may be compared by measurements with calipers (Figs. 8 and 9).

Measurements so made show the following relationships:

The first sound is associated with a peak or notch on the systolic limb of the ventricular wave, indicating a very rapid and small movement of the ventricle. It has no corresponding record on the aortic wave.

The second sound corresponds in time to the end of systole and is associated with a very rapid and small and inconspicuous peak arising from the deepest portion of the trough of the ventricular wave just before the beginning of diastole.

The aortic and pulmonary artery waves, however, show a conspicuous angulation in the down limb of the wave (corresponding to the inward movement of the vessel), a short distance from the peak of the maximum outward thrust. This corresponds in time to the second sound. It occurs about one-fifth of a second after the beginning of the retraction. It is apparent, therefore, that the phenomena associated with the heart sounds produce vibrations of the heart and aortic walls of sufficient intensity to be recorded on the roentgenkymographic waves, and that kymography furnishes not only a method of recording cardiac movement, but also cardiac sounds.

SUMMARY

The kymographic method contributes the following information to the morphologic and physiologic study of the heart:

1. The actual make-up of the cardiac shadow.
2. The shape of the heart as a whole, or any of its chambers during the various phases of movement.
3. Size of the heart in systole and diastole or any intermediate phase.
4. Characteristics of the movement of the heart as a whole or of its various chambers.
5. Activity and accomplishment of the cardiac muscle.
6. The relationship of contraction to conduction phenomena.
7. The relationship of movement to sound phenomena.

The author acknowledges his deep appreciation of the assistance rendered him by Dr. Myron Schwarzschild, physicist of the Beth Israel Hospital, in the work upon which this paper is based.

(End of Part I)

AN ANALYSIS OF A GROUP OF PRIMARY NEWGROWTHS OF THE LUNGS, TREATED WITH DEEP X-RAY THERAPY[1]

By WILLIS F. MANGES, M.D., *Philadelphia*

THIS analysis has to do with 27 cases. The diagnosis in each case is based on the histologic study of tissue removed by means of the bronchoscope in the hands of Dr. Jackson or Dr. Clerf, and in one case by Dr. Tucker—by surgical means or at the autopsy table. Wassermann and Kahn tests were made in all of the cases and were found to be positive in one. The histologic studies were made by Dr. Crawford, pathologist at the Jefferson Hospital. There was clinical and roentgenographic evidence to support the histologic diagnosis, which in each instance was malignant. More specifically, the histologic diagnosis was: carcinoma in 11; squamous-cell carcinoma in 6; carcinoma (undifferentiated) in 4; adenocarcinoma in 3; endothelioma in 1; epithelioma in 1, and one case diagnosed carcinoma from a gland removed surgically from the anterior chest wall.

Crawford and Clerf have restudied all of these cases and others in the past year and have reclassified them. As a result of this review, the histologic diagnoses of these same 27 cases are now as follows: adenoma or other benign growth in 5 (including one diagnosed elsewhere as carcinoma); carcinoma (undifferentiated) in 5; adenocarcinoma in 2; squamous-cell carcinoma in 14; carcinoma from metastatic gland in 1.

The age limits of these patients were: 24 years for the youngest; 69 for the oldest; three in the twenties; four in the thirties; twelve in the forties; four in the fifties; four in the sixties. The ages of the benign group ranged from 24 to 40; of the malignant group from 38 to 69.

One case out of this group of 27 cases was treated by Dr. Leo Paul Larkin, of Ithaca, New York. It is included here because the diagnostic studies were made in the Jefferson Hospital, and it has an important bearing on subsequent events.

Of the benign group of five: two are living 9 years and 8 months since the original diagnosis and roentgen-ray treatment, one of these having had recurrence of all symptoms and a second histologic diagnosis of carcinoma in a little more than 4 years, but has remained well as result of the second roentgen-ray treatment; one is living 6 years (treated at the Jefferson Hospital, but his bronchoscopy and histologic diagnosis of carcinoma were made at the University of Pennsylvania Hospital); another is living 3 years and 7 months since treatment, and the last of the group 3 years and 3 months.

Of the group of five now considered to have carcinoma undifferentiated, one is living 4 years following her first treatments. She has had a second series, because of recurrence of hemoptysis. From recent observations it seems likely that she may die of cardiac disease, rather than of carcinoma. The original lung tumor remains evident, but considerably smaller, whereas her heart has progressively increased in size. Another of this group lived 8 months after treatment; two lived 3 months, and one we have not been able to trace.

Of the two adenocarcinoma cases, one lived 4 months; the other 6 months.

The tenure of life in the group finally diagnosed as squamous-cell carcinoma ranged as follows: one lived 2 years, 3 months; one lived 2 years; one lived 1 year, 2 months; one lived 1 year; one lived 10 months; two lived 9 months; one lived 7 months; two lived 3 months; two lived 2 months, and two have not been traced. That one patient of this group who lived 1 year after treatment had injections of lead prior to the roentgen-ray treatment. The case diagnosed from a

[1]Read before the American Congress of Radiology, at Chicago, Sept. 25-30, 1933.

metastatic gland lived 2 months after treatment.

The majority of the patients came for treatment only after the disease was well advanced, many of them being really too sick to receive efficient treatment. Most of them had either massive areas of density due to a tumor mass, exudate-filled lung, or collapsed lung.

The duration of symptoms prior to diagnosis varied from 2 weeks to 3 years or more. It is by no means clear in more than a few of them that the newgrowth existed at the time of the onset of symptoms, so that it is impossible to strike an accurate average duration of existence of the growth prior to treatment. However, as nearly as can be estimated, the average duration of symptoms in the benign group was 11 months; in the undifferentiated, 5 and a half months; in adenocarcinoma, 3 months, and in the squamous-cell group, 8 months.

The clinical picture is not characteristic but if one records the cases that have definite pain, cough, dyspnea, hemoptysis, and loss of weight, we find that these symptoms have a great deal of bearing on the diagnosis. In this series of 27 cases, 19 had definite pain; 25 had cough; 13 had definite dyspnea; 15, hemoptysis; 19, noticeable loss of weight. One of the squamous-cell cases had pain, another had loss of weight only. One of the undifferentiated cases had only cough and loss of weight. The other patients had three or more of the above symptoms, and, also, quite a number had all five symptoms.

It is true that cough, dyspnea, and pain, as well as loss of weight, are symptoms of other diseases, and hemoptysis, of course, has always been looked upon as possible evidence of tuberculosis, but if one resorts to the expedient of examining the sputum carefully, the presence of active tuberculosis should be eliminated with fair ease. Roentgenographically (1), this is sometimes not possible because there are cases that give somewhat the appearance of a tuberculous lesion. Hemoptysis is so important a sign in the diagnosis of primary newgrowth of the lung that one should assume it to be necessary to exclude primary newgrowth rather than to exclude tuberculosis. Cough is but an expression of bronchial irritation and is, of course, the most constant symptom. It is easily explained in those cases that have had chronic infections over a long period of time, but in quite a few of the patients cough was the first definite evidence of the disease and the other symptoms developed rather promptly after the cough started.

The amount of radiation given has varied to a considerable extent, the aim in each instance being to deliver effective radiation in the depth of the lesion. Patients with short thoracic diameters had treatment through two portals of entry; however, most of them had treatment through three portals, one anterior, one posterior, and one lateral on the side of the lesion. One of the benign patients weighed approximately 300 pounds, so that over each of the three areas he was given a sufficient amount of radiation to produce a very marked skin reaction. The dosage was necessarily limited in some patients by reason of their inability to tolerate the treatment. As a rule, the saturation method was used.

The change in the area, as shown roentgenographically, also varied after treatment to a considerable extent. In one of the benign cases, living more than 9 years, the area of density is smaller than it was originally but is still present because of the chronic infection of bronchiectasis that still exists. Another of the benign cases, the one weighing 300 pounds, developed quite a large area of density in the field of treatment, due, I believe, to the effect of the heavy radiation. This increased area of density subsided after a period of many months. In some of the cases the tumor mass disappeared entirely but later recurred, as illustrated by the squamous-cell case that lived 2 years and 3 months after the first series of treatments. The tumor mass again disappeared after a second series, but recurred the second time and caused death. In another case, one of the undifferentiated carcinomas, the

tumor mass has gotten smaller but in other respects has not changed for more than 4 years, and the patient is still living.

Summarizing the group in this respect, we have: 13 in whom the area of density showed definite diminution within a month following treatment; two in whom it actually increased; two in whom it disappeared; four in whom there was no appreciable change; five in whom we have no record of the condition after radiation, and one case treated elsewhere.

The important group of this series is the one made up of the five cases that are now considered to be benign, whereas formerly they had been diagnosed as malignant. In each instance, the growth may not have been malignant but certainly was in a fair way to terminate the patient's life. The fact that these patients remain well as a result of treatment emphasizes the value of the treatment and the importance of accurate diagnosis. In view of the revision in diagnosis in this group and the results of treatment, one might assume that there is a primary bronchial growth that bears somewhat the same relation to carcinoma that giant-cell tumor does to sarcoma, insofar as response to radiation therapy is concerned. Cases of this kind should not be submitted to radical surgery.

About a year ago, Vinson and Leddy (2) reported the results of roentgen-ray treatment in 32 cases. At that time, 10 of their cases were living from 15 months to 4 years after treatment. It would be extremely interesting to compare the histologic character of that group with the 5 cases here reported as benign. It is entirely probable that some of them at least would be found to be similar.

It would seem quite worth while if histologic slides, roentgenograms, treatment records, and other data of all cases of primary newgrowth of the bronchi could be collected and studied by a selected group of clinicians, roentgenologists, bronchoscopists, surgeons, and pathologists, and then be reported from time to time.

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SUMMARY

Diagnosis as a rule is not made until the lesion is well established.

Differential diagnosis of primary newgrowth of the bronchus should be made by histologic study of tissue whenever possible.

Five of a group of 27 cases are now considered benign, whereas at the time of first study the histologic diagnosis was malignant. These five are living from 3 to 9 years after roentgen-ray therapy.

There is positive evidence of prolongation of life and amelioration of symptoms in many definitely malignant cases.

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WATER PHANTOM INTENSITY MEASUREMENTS OF HIGH VOLTAGE ROENTGEN RAYS (200 K.V. PEAK) AT 70 AND 80 CM. SKIN-TARGET DISTANCE[1]

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THE question often arises in the treatment of deep-seated tumors as to the best method of delivering a predetermined dose of radiation and still do the least amount of damage to the intervening skin and normal tissue. Some radiologists advocate using a greater skin-target distance than the usual 50 cm., some the use of more filtration, higher voltages, and others a combination of the different factors. This paper deals only with a variation in the skin-target distance.

It is well known that if the skin-target distance is increased, the number of milliampere-minutes will be increased to give an equivalent roentgen dose. This increase in milliampere-minutes can be computed by applying the inverse square law

$$\frac{I_{50}}{I_{80}} = \frac{(80)^2}{(50)^2} = \frac{6400}{2500}$$

$$I_{50} = 2.56\ I_{80}$$

where I_{50} is the intensity of 50 cm. S.T.D. and I_{80} is the intensity at 80 cm. S.T.D. In the same manner

$$I_{50} = 1.96\ I_{70}.$$

The increase in time necessary to produce a given number of roentgen units can be somewhat reduced by a greater depth dose at 70 and 80 cm. S.T.D. than at 50 cm. S.T.D. In order to determine the greater depth dose, water phantom ionization measurements were made at 70 and 80 cm. S.T.D. for varying sized fields of radiation. The x-ray machine (mechanical rectification) was operated at 200 K.V. (peak), and 5 milliamperes, with a filtration of 0.5 mm. Cu and 2 mm. Al, and a half layer value of 0.80 mm. Cu.

The method of making water phantom ionization measurements has been previously described (1–4).

In order to determine the efficacy of an increased skin-target distance greater than 50 cm., it is necessary to draw an anatomical chart of the patient and apply isodose charts to determine the depth dose of roentgen radiation at the different skin-target distances (4, 5).

For the purpose of making comparisons, anatomical cross-sections, all with 22 cm. anteroposterior and 30 cm. lateral dimensions, are shown, with indicated skin and tumor intensities for two, three, and four fields at 80 cm. and four fields at 50 centimeters. Even though an anatomical chart of the cervical region is the only one shown, the same will apply to any other involved areas (7).

[1] Read at the Eighteenth Annual Meeting of the Radiological Society of North America, at Atlantic City, Nov. 28–Dec. 1, 1932.

TABLE I.—RELATIVE DEPTH INTENSITIES

Depth in water	20 cm. dia. field S.T.D.			16×16 cm. field S.T.D.			14×14 cm. field S.T.D.			10×8 cm. field S.T.D.			6×8 cm. field S.T.D.		
	50	70	80	50	70	80	50	70	80	50	70	80	50	70	80
Half sub.	100	100	100	100	100	100	100	100	100	100	100	100	100	100	100
2 cm.	95	97	98	92	95	98	92	94	97	91	93	94	88	92	94
5 cm.	72	76	78	69	75	78	67	70	77	64	68	70	59	63	68
7 cm.	57	62	64	52	60	64	51	58	62	49	52	53	42	48	52
10 cm.	39	45	47	35	43	46	33	41	44	30	36	38	26	33	38
15 cm.	18	24	27	17	23	26	15	22	26	13	19	21	11	18	20
20 cm.	8	13	16	7	12	16	6	11	14	4	10	13	3	10	11

Applying two fields to a patient measuring 22 cm. anteroposterior and 30 cm. lateral, the tumor intensity is approximately 95 per cent, while the intensity on each skin area is 115 per cent. The tumor area will receive less radiation than each skin area. The relative skin and tumor doses are computed as follows (Fig. 2):

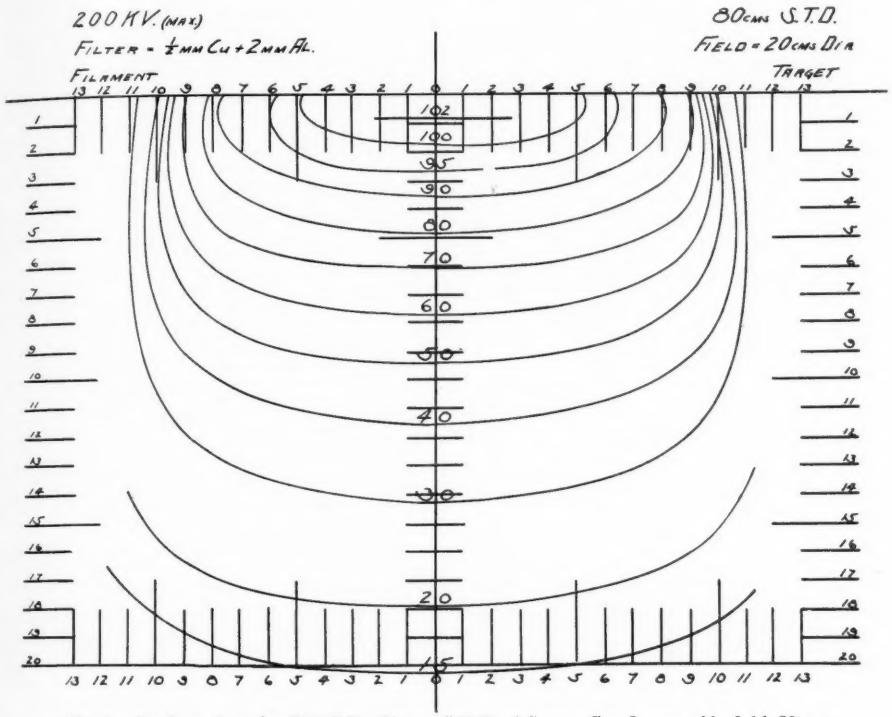

Fig. 1. Isodose chart for 200 K.V., 80 cm. S.T.D., 0.5 mm. Cu, 2 mm. Al, field 20 cm. diameter.

Tumor intensity : skin intensity : : X : 100 per cent.

Substituting,

95% : 115% : : X : 100%

115%X = 95% × 100%

X = 83% E.S.D. = Tumor dose when each skin area receives 100% E.S.D. (Fig. 2).

Therefore, when each skin area receives 100 per cent of the predetermined erythema dose, the tumor receives 83 per cent.

If the radiologist wishes to give 100 per cent predetermined erythema dose of radiation to the tumor, it is necessary to change the proportion to:

Skin intensity : tumor intensity : : X : 100 per cent.

Substituting,

115% : 95% : : X : 100%

95% X = 115% × 100%

X = 121% E.S.D. Skin dose when tumor receives 100% E.S.D. (Fig. 2).

If the tumor is to receive 100 per cent predetermined dose of radiation in roentgens, it will require approximately 121 per cent of the dose to each skin area. By inspection of Figure 2, it is seen that with two fields, more radiation must be applied to each skin area than can be delivered to the tumor area.

The two oblique fields show a skin intensity of 110 per cent, while the one perpendicular field shows a skin intensity

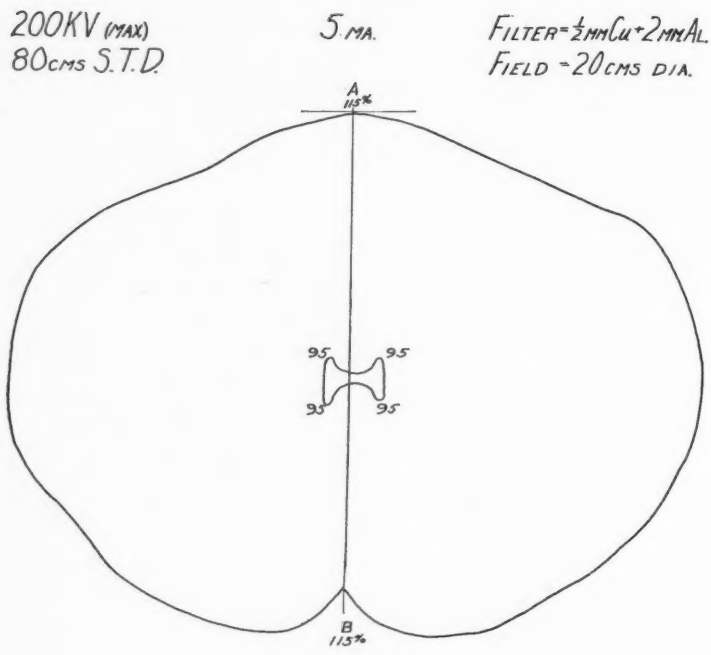

Fig. 2. Anatomical cross-section showing (1) tumor intensity from two fields at 80 cm. S.T.D. and (2) skin intensity.

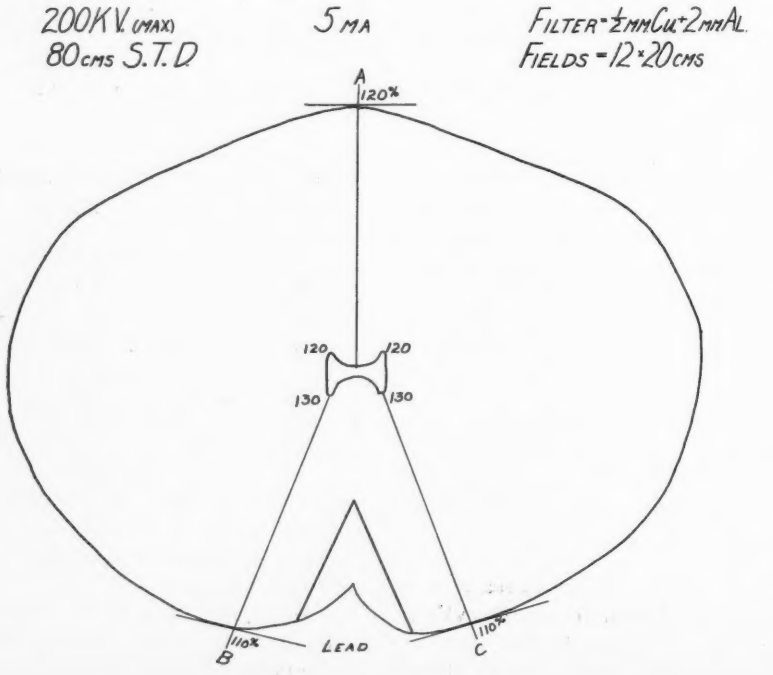

Fig. 3. Anatomical cross-section showing (1) tumor intensity from three fields at 80 cm. S.T.D. and (2) skin intensities.

of 120 per cent (Fig. 3). The tumor intensity is approximately 125 per cent. In order to give a tumor 100 per cent of an

In applying two anteroposterior fields (Fig. 2), it is seen that with the patient measuring 22 cm. anteroposterior and 30

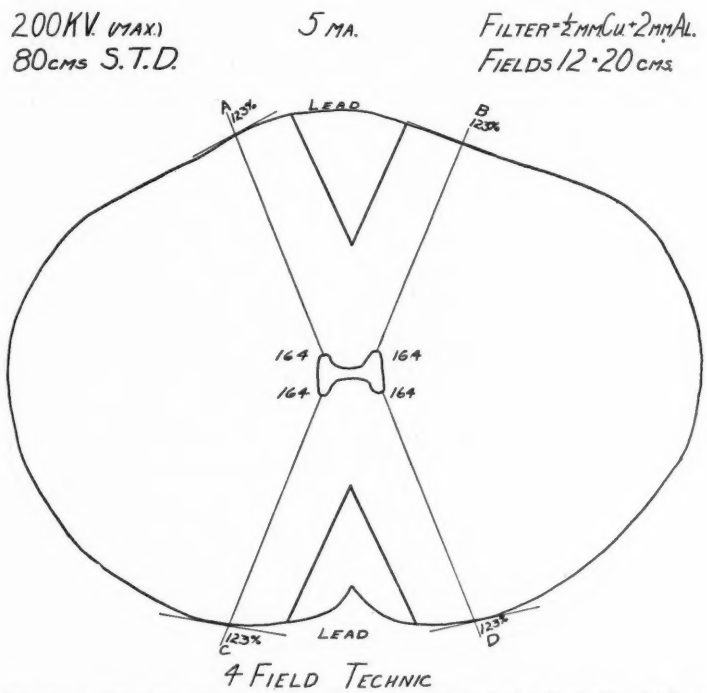

Fig. 4. Anatomical cross-section showing (1) tumor intensity from four fields at 80 cm. S.T.D. and (2) skin intensity.

E.S.D., the skin intensity of the large field, 20 cm. in diameter, will receive 96 per cent E.S.D. as,

$$120\% : 125\% :: X : 100\%$$
$$X = 96\% \text{ E.S.D. (Fig. 3).}$$

To give the tumor 100 per cent E.S.D., each skin area will receive 75 per cent E.S.D. as,

$$123\% : 164\% :: X : 100\%$$
$$X = 75\% \text{ E.S.D. (Fig. 4).}$$

To give the tumor 100 per cent E.S.D., each skin area will receive 91 per cent E.S.D. as,

$$107\% : 118\% :: X : 100\%$$
$$X = 91\% \text{ (Fig. 5).}$$

cm. lateral, the skin intensity exceeds the tumor intensity. By reducing the anteroposterior and lateral dimensions of patients, the depth intensity will increase, but at the same time the transmitted radiation will also increase so that the skin intensity remains greater than the tumor intensity.

In comparing the relationship in milliampere-minutes to two anteroposterior fields at 80 cm. with four fields at 50 cm. S.T.D., it has been shown by the inverse square law that the time required to produce the same number of roentgens per minute at 50 cm. S.T.D. is 2.56 times greater than the time at 80 cm. S.T.D. Four fields, therefore, can be treated with a less number of milliampere-minutes at 50 cm. S.T.D., than two fields at 80 cm. S.T.D.

Comparing Figures 2 and 5, it is seen

that with the two-field technic at 80 cm. S.T.D., each skin area receives a larger dose than the tumor, while with the four-field technic at 50 cm. S.T.D., the tumor receives a larger dose than either skin area.

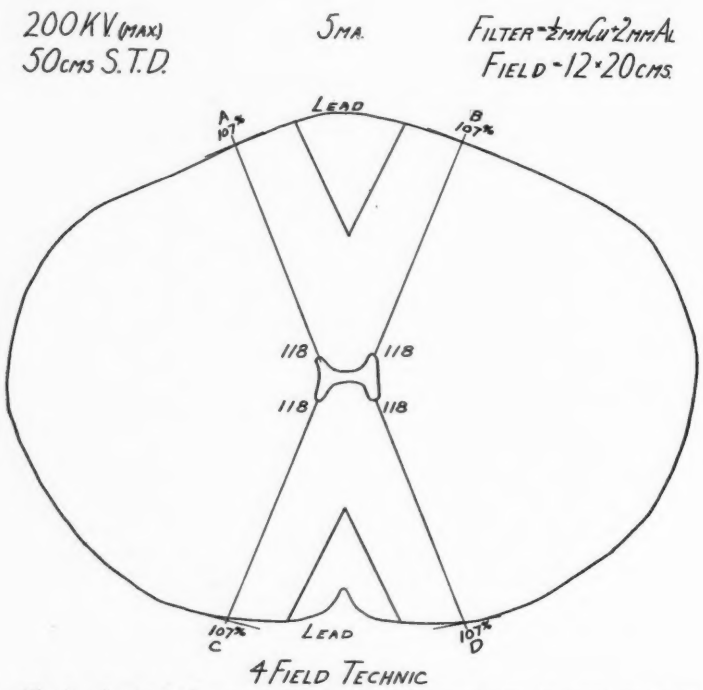

Fig. 5. Anatomical cross-section showing (1) tumor intensity from four fields at 50 cm. S.T.D. and (2) skin intensity.

Comparing Figures 3 and 5, it is seen that the tumor receives more radiation than either skin area with three fields at 80 cm. S.T.D., as well as with four fields at 50 cm. S.T.D. The three-field technic at 80 cm. S.T.D. gives a slightly greater tumor dose than at 50 cm. S.T.D. However, it requires approximately 1.8 times the number of milliampere-minutes at 80 cm. S.T.D. to deliver 100 per cent E.S.D. to the tumor as compared to 50 cm. S.T.D.

Comparing the four-field technic as shown in Figures 4 and 5, it is seen that each skin area receives 75 per cent E.S.D. when the tumor receives 100 per cent E.S.D. at 80 cm. S.T.D. Here there is a distinct advantage in the use of a greater skin-target distance.

If the radiologist finds that a tumor area of a patient cannot be adequately treated without injuring the skin and intervening tissue with a four-field technic at 50 cm. S.T.D., then an increase in the skin-target distance is indicated. In such cases, time can be sacrificed to obtain a better depth dose.

If the patient has been irradiated to the point at which it is advisable to conserve intervening normal skin and tissue as far as possible and the radiologist is still desirous of further irradiating the tumor, a greater skin-target distance is preferable.

SUMMARY

1. By the inverse square law it is shown how the radiation changes with a variation in the skin-target distance.

2. An isodose chart giving the distribution of roentgen radiation for 80 cm. S.T.D. is shown in Figure 1.

3. The depth intensities of roentgen radiation from 50, 70, and 80 cm. are shown in Table I.

4. Isodose curves for 80 cm. S.T.D. are applied to an anatomical cross-section chart of a patient using two, three, and four fields as shown in Figures 2, 3, and 4. Isodose curves for 50 cm. S.T.D. are applied to the same anatomical chart as shown in Figure 5. Comparisons are made of the relative skin and tumor doses with accompaning changes in the intensities.

5. The radiologist is justified in increasing the skin-target distance

(*a*) to obtain a better depth dose when treating large patients;

(*b*) to further increase the tumor dose over the skin dose in order to preserve, as far as possible, the intervening skin and normal tissue.

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THE RELATIONSHIP OF SINUS DISEASE TO CHEST DISEASE IN CHILDREN[1]

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NON-TUBERCULOUS infections of the lung, especially those outside the group comprised of foreign bodies, abscesses, and similar pathologic conditions, have occupied the interest of various investigators for some time (1,2,3). Despite this fact, there is still much to be learned about them (4,5,6). They are often erroneously classified and diagnosed as tuberculosis. Pulmonary tuberculosis, on the other hand, after many years of study is fairly well understood. Since the infant and young child appear to be quite susceptible to this kind of infection, it seems important to make a study of the various parts of the respiratory tract in the infant and the child and to endeavor to see if any relationship exists between infection of one part and that of another.

There are at least three methods of approaching this study: First, a large number of cases may be selected that have shown infection, and then a follow-up made to determine the course of the disease; second, a number of children at any given age, some of whom are evidently normal and some of whom show disease, may be studied. (Either of these two methods tends, however, to give only a cross-sectional view at certain age levels.) Third, a group of children may be studied periodically, starting from time of birth. Under this method, the child is studied before, or at least near the time of, onset of the disease. In studying the infant from birth onward, it is possible to watch for minute changes in the course and progress of non-tuberculous infections (7). If, in selecting such a series, a group is chosen not because it is particularly free or particularly susceptible to upper respiratory disease, but because it represents an average group, we believe we will then be more successful in getting a true picture of the average child. In this report we have utilized information obtained by all three methods.

The respiratory tract is the only one directly open to the outside air. It is composed of the accessory sinuses, mastoids, nasal and oral pharynx, larynx, trachea, bronchi, and terminal air cells, as one continuous tube with certain regional anatomical divisions. It is our problem to study the relationship of infection in the sinuses and lungs which are at the opposite ends of the tract. The path which infection may take from the sinuses to the lungs has had considerable study. Mullin, in an experiment on rabbits, demonstrated a lymphatic connection between the sinuses and lymph nodes at the roots of the lungs (1, 8). It is also possible that infection takes place by direct extension, that is, by contiguity and by continuity, by the blood, or by air column transmission. Whether it is by Mullin's method (lymphatic extension) or by some other or by all, is a problem which needs much more investigation. However, the point which we wish to emphasize here is that the organs of the respiratory tract constitute a single and continuous cavity.

The sources of material for this study fall into three groups which were chosen to represent the three possible methods of approach. For the first method, a study was made of 58 cases (some of known non-tuberculous infection) recorded and followed at the Child Research Council, Denver, and spoken of herein as the "special series." For the second method, material came from examination of the roentgen records of children seen in private practice and at Children's Hospital,

[1] Read before the American Congress of Radiology, at Chicago, Sept. 25–30, 1933.

Denver, by one of us (W. W. W.). For the third method, we studied the records of 100 children followed at the Child Research Council, Denver, since birth. The material obtained from study of the first and second groups is used in this report to check upon the findings reported in regard to the third group of 100 children followed from birth, which forms the chief basis for this study.

It is not the purpose of this paper to review the extensive literature on the subject of sinus infection or non-tuberculous chest infections, but to endeavor to determine if there is a relationship of sinus disease to chest disease as shown by the material already described. In non-tuberculous chest disease, the sinuses are often said to be responsible for lung infection. Whether the chest disease results from sinus infection or *vice versa*, or whether it is not rather a coincidence by which the whole cavity is equally infected is a problem not settled. However, it is in the sinuses and chest that the manifestations of the infections are apparent in a roentgen examination.

As stated before, our chief sources of material are the records of 100 children studied from birth. Periodic examinations are made on each child at intervals of approximately three months, consisting of detailed clinical, laboratory, and roentgenologic studies. The present ages of the children (52 boys and 48 girls) range from three months to eleven years. Table I gives the number of children and the ages at present.

TABLE I

Age	Number of cases
3 months to 6 months	7
6 months to 1 year	14
1 year to 2 years	16
2 years to 3 years	16
3 years to 4 years	8
4 years to 5 years	6
5 years to 6 years	9
6 years to 11 years	24
Total	100

The roentgenograms which had been made at intervals of three months were assembled upon a large illuminator, specially constructed to display 75 films simultaneously. Evidence of infection which began in infancy could be studied in this way and followed throughout its entire course from birth to the present date.

DISCUSSION OF DATA

1. *The Sinuses.*—In studying the sinuses of this group, the seven cases which were under six months of age are not reported, because we believe that a single roentgenologic examination is not sufficient to establish even a roentgenologic diagnosis of sinusitis in children, especially where there is no clinical evidence of such disease. At the time of delivery, the sinuses do not contain air. Aeration is gradual until they become fully aerated at from four to eight weeks (9, 10). After that, decreased aeration is indicative of mucous membrane change as well as allergic or infectious changes. Hence, in our discussion the word "disease" is used rather than "infection," as "disease" implies that there may be mucous membrane changes, allergic conditions, infection, or a combination of these conditions. Sinus disease as evidenced by decreased aeration or thickening of the borders of the sinuses has been classified in this study as (1) mild, (2) moderate, and (3) severe chronic or recurrent. The term "mild disease" is used to indicate those cases in which only a few examinations show slightly decreased aeration of the sinuses. "Moderate disease" designates those changes which show a more marked decrease in aeration, occurring in a greater number of instances. By "severe chronic sinus" disease or "recurrent sinus" disease is meant those cases which show in a large number of examinations a marked decrease in aeration of one or more sinuses.

It is interesting to note that in one case followed for ten years two examinations show both maxillary sinuses with markedly thickened borders, while every other examination shows them excellently aerated. In another case followed for seven years, there has been a recurrent sinus, disease yet

on several examinations the sinuses show good aeration with clear-cut borders. For this reason we believe that it is unwise to make a diagnosis of the presence or absence of true sinus disease upon the evidence presented by one roentgen examination.

In the 93 cases from nine months to eleven years, 71 show the presence of sinus disease, the majority of which occur in the highest age group. That is, of the 34 children between the ages of five and eleven years, only two fail to show infection at some time. However, it must be borne in mind that 34 children comprise too small a group from which to generalize. The results of the study of the sinuses are given in Table II.

TABLE II.—CASES STUDIED FROM BIRTH

	Ages at last examination		
	Birth to 3 years	3 to 5 years	5 to 11 years
Cases showing no disease	6	4	2
Cases showing doubtful disease	7	0	0
Cases showing slow clearing of the sinuses after birth, but, once cleared, then good aeration	2	1	0
Mild sinus disease	4	0	3
Moderate sinus disease	22	1	19
Chronic or recurrent sinus disease	4	8	10
Totals	45	14	34

2. *Chest Diseases.*—Of this group of 93 cases, only those above the age of two years and six months (57 cases) are reported as to the presence or absence of non-tuberculous infections. A diagnosis of non-tuberculous infection before the age of two years and six months we believe to be extremely difficult, because it is only from the subsequent examinations that the presence of non-tuberculous pulmonary disease may be established. There may be evidences of inflammatory changes but they have not as yet established themselves sufficiently to warrant such a diagnosis. The entire group of 100 cases was, however, studied in regard to the presence of tuberculous infection. It must be remembered that the series of 100 cases followed from birth consists of apparently healthy children. Consequently, the majority of these cases fall into that puzzling group which so often confronts the roentgenologist, namely, borderline cases between the normal and the diseased, between tuberculous and non-tuberculous pulmonary diseases. As a check upon our diagnosis, in these borderline cases we have made use of selected cases from our other two groups, *i.e.*, the special series, and hospital and private cases. Here we have clear-cut pictures of the infection supported by clinical evidence for comparison.

The difficulty in diagnosis of the borderline cases, especially under two years and six months, may be dependent upon several important factors of technic which have to do with correct portrayal. First, the roentgenogram must be absolutely free of movement, and those familiar with making a roentgenographic study of infants will appreciate how difficult this is even with an exposure of one-twentieth of a second, which we use as a matter of routine. Second, in children under two to three years of age, it is often difficult to obtain the desired degree of inspiration. Roentgenograms showing poor inspiration completely defeat any attempt to diagnose this type of chest disease. The increased hilar width, accentuation of peribronchial and perivascular marking, and blurring of lung detail, that are apparent on roentgenograms showing poor inspiration, so closely resemble the non-tuberculous type of chest disease that a diagnosis is frequently impossible. Third, and certainly of equal importance, is the constantly changing structure of the infant chest (11). It not only grows in size but there is a gradual change from the infant to the so-called adult type of chest markings. In our study, this change is progressive but does not conform to any certain age level. The change has been most marked, however, in the first two to three years. In short, it is imperative that the diagnostician be familiar with the changes in the infant chest that are due to natural growth (12). The borderline between a normal growth of connective

tissue surrounding the lung structures and that produced by a disease process is at times difficult to determine and evaluate (13, 14). In fact, we have been unable to find in the literature accurate reports of the normal amount of connective tissue in the lungs at various age levels (15, 16). Our method has been to study these cases from birth and to arrive at a conception of average chest markings in the infant by using the subsequent examinations as criteria. In regard to connective tissue, it is well to remember that we are dealing not with acute but with chronic changes, and we are not always able to state exactly the nature of the change until a year or so after it has occurred. Chest diseases accompanying sinus disease appear to be, in our series, of a markedly chronic nature. Because of the difficulty in determining where normal growth of connective tissue ends and disease starts in the infant chest, we deem it advisable to begin our report of the presence or absence of pulmonary disease in association with upper respiratory infection at the age of two years and six months. In some cases, having once demonstrated the pathologic lesion at a later age, it is possible to return to the infant chest of two years and under and show the beginning of the inflammatory change. However, an attempt to make a diagnosis at this early age is beset with difficulties, as outlined above. This we think is one of the greatest arguments in favor of a diagnosis based upon frequent examinations at regular intervals throughout childhood, rather than one based upon a single examination or even several examinations.

TABLE III.—CASES STUDIED FROM BIRTH

	Ages at last examination		
	Birth to 3 years	3 to 5 years	5 to 11 years
No disease process noted	9	7	6
Evidence of non-tuberculous infection	2	6	20
Non-active tuberculosis with superimposed upper respiratory disease	0	0	2
Non-active tuberculosis, with calcification or fibrosis	1	0	4
Totals	12	13	32

The results of our study of the chests in this series are shown in Table III.

3. *Sinus Disease in Relation to Chest Disease.*—In correlating the cases of sinus disease and chest disease, only those cases from two years and six months or over are reported (see above). The results of the correlation are shown in Table IV.

An analysis of Table IV shows that there are three cases followed from birth to three years which give evidence of mild sinusitis but which show no chest changes. There are no cases of mild sinusitis in either of the higher age groups. Moderate sinus disease and an absence of chest changes are noted in three of the group followed from birth to three years, two from three to five years, and six from five to eleven years. However, of 19 cases of moderate disease in the third group (five to eleven years), 13 show definite evidence of chest changes. Of the 17 cases of chronic or recurrent sinus disease with definite chest changes, two are in the first age group, five in the second, and ten in the third. The three cases of chronic or recurrent sinus disease which

TABLE IV.—CASES STUDIED FROM BIRTH

	Ages at last examination					
Sinus infection	With chest changes			Without chest changes		
	Birth to 3 years	3 to 5 years	5 to 11 years	Birth to 3 years	3 to 5 years	5 to 11 years
Mild sinus disease	0	0	0	3	0	0
Moderate sinus disease	0	0	13	3	2	6
Chronic or recurrent sinus disease	2	5	10	0	3	0
Totals	2	5	23	6	5	6

Fig. 1-A.

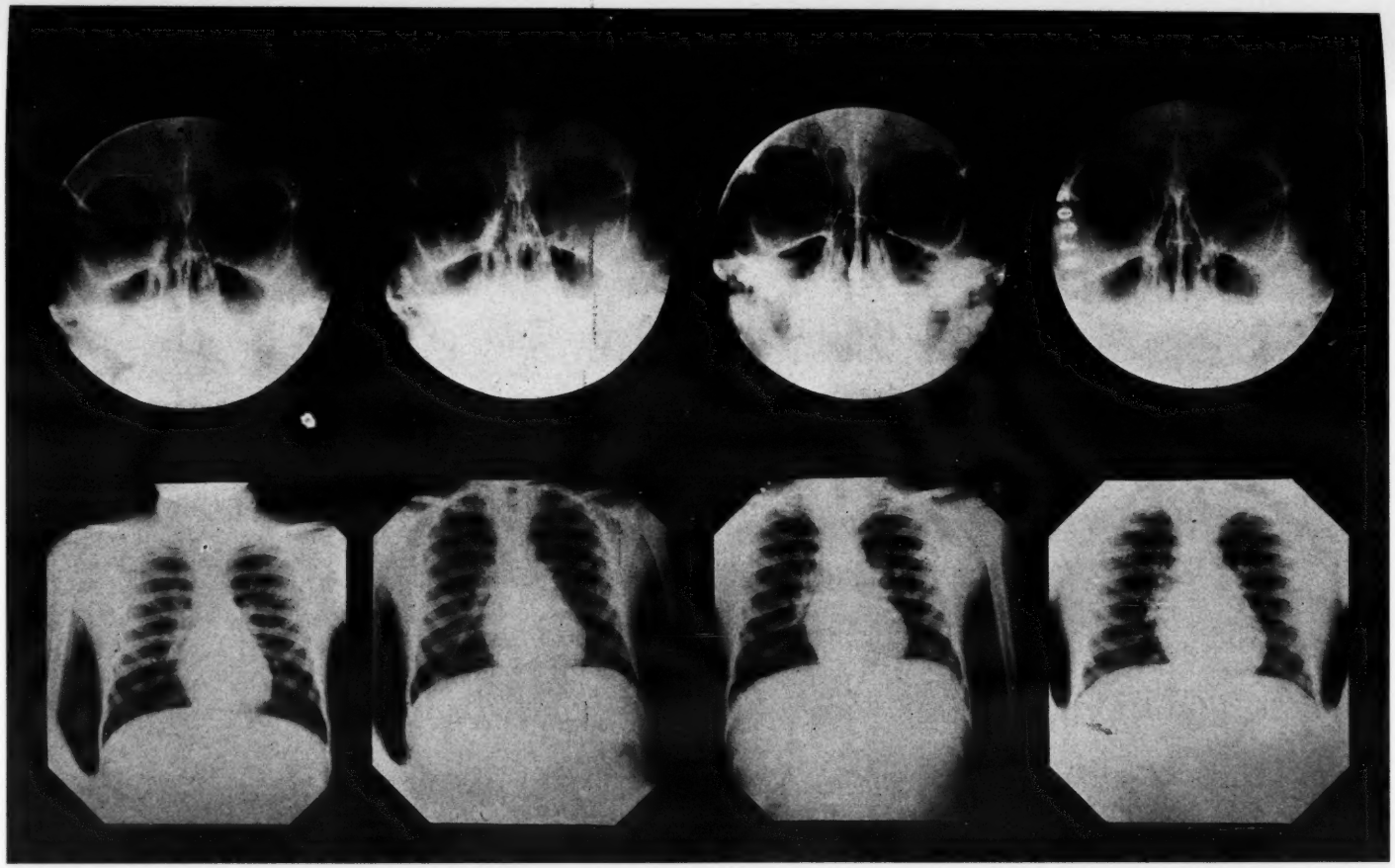

Fig. 1-*B*.

Fig. 1. *Clear Sinuses and Healthy Chest.* Roentgenograms selected at yearly intervals from 3 to 10 years from a series of 42 chest and sinus examinations on the same child. Note the good aeration throughout the series. Compare with Figure 2.

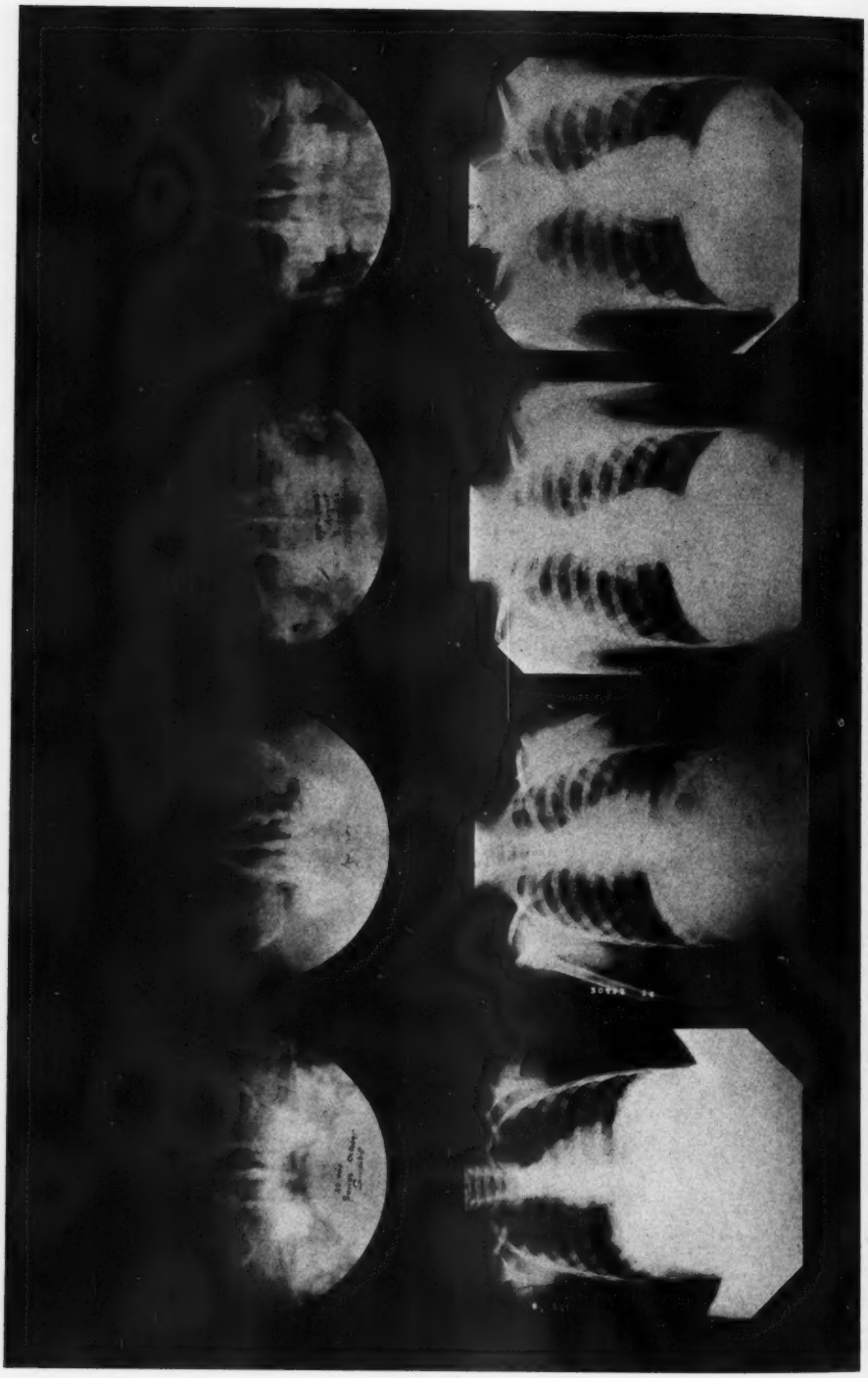

Fig. 2-4.

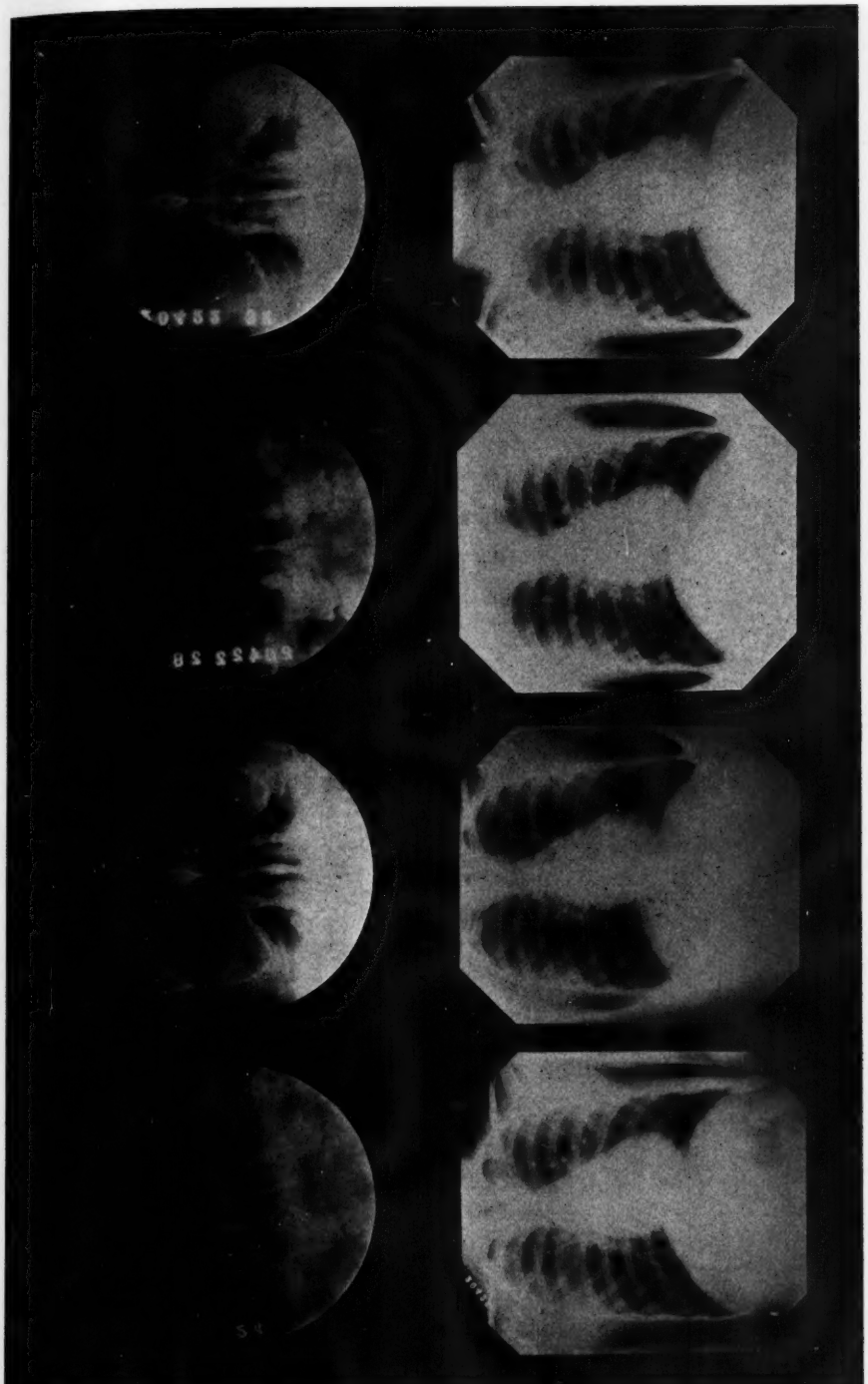

Fig. 2-*B*.

Fig. 2. *Diseased Sinuses and Chest Disease.* Roentgenograms selected at yearly intervals from 3 to 10 years from a series of 39 sinus and chest examinations on the same child. Note lack of aeration throughout the series, and at no time are the sinuses as clear as in the clear series. Compare with Figure 1.

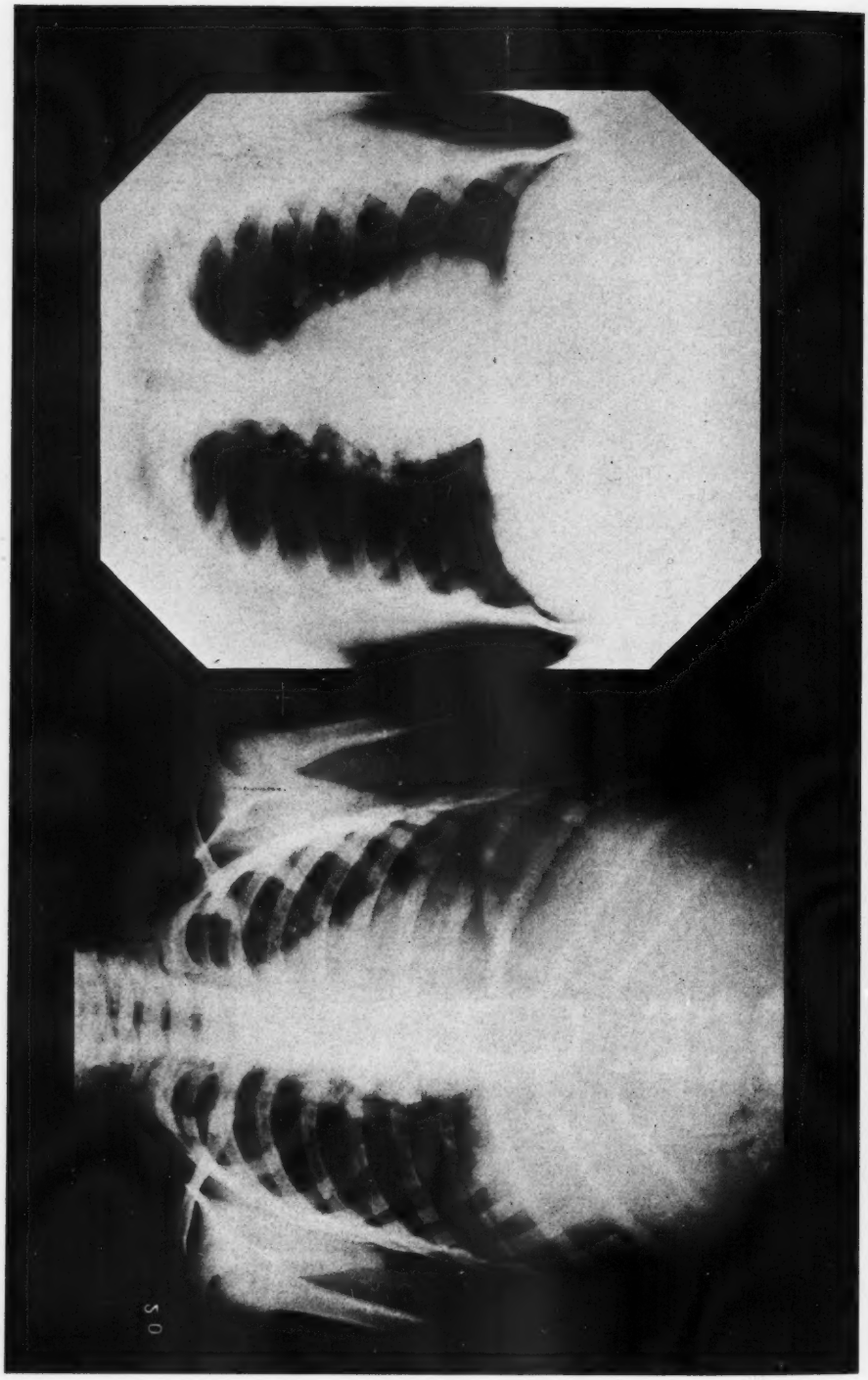

Fig. 3. *Healthy Chest.* Enlargements of the 3- and 10-year roentgenograms as shown in Figure 1. The peribronchial and perivascular markings may be best studied with a hand lens. Compare with Figure 4.

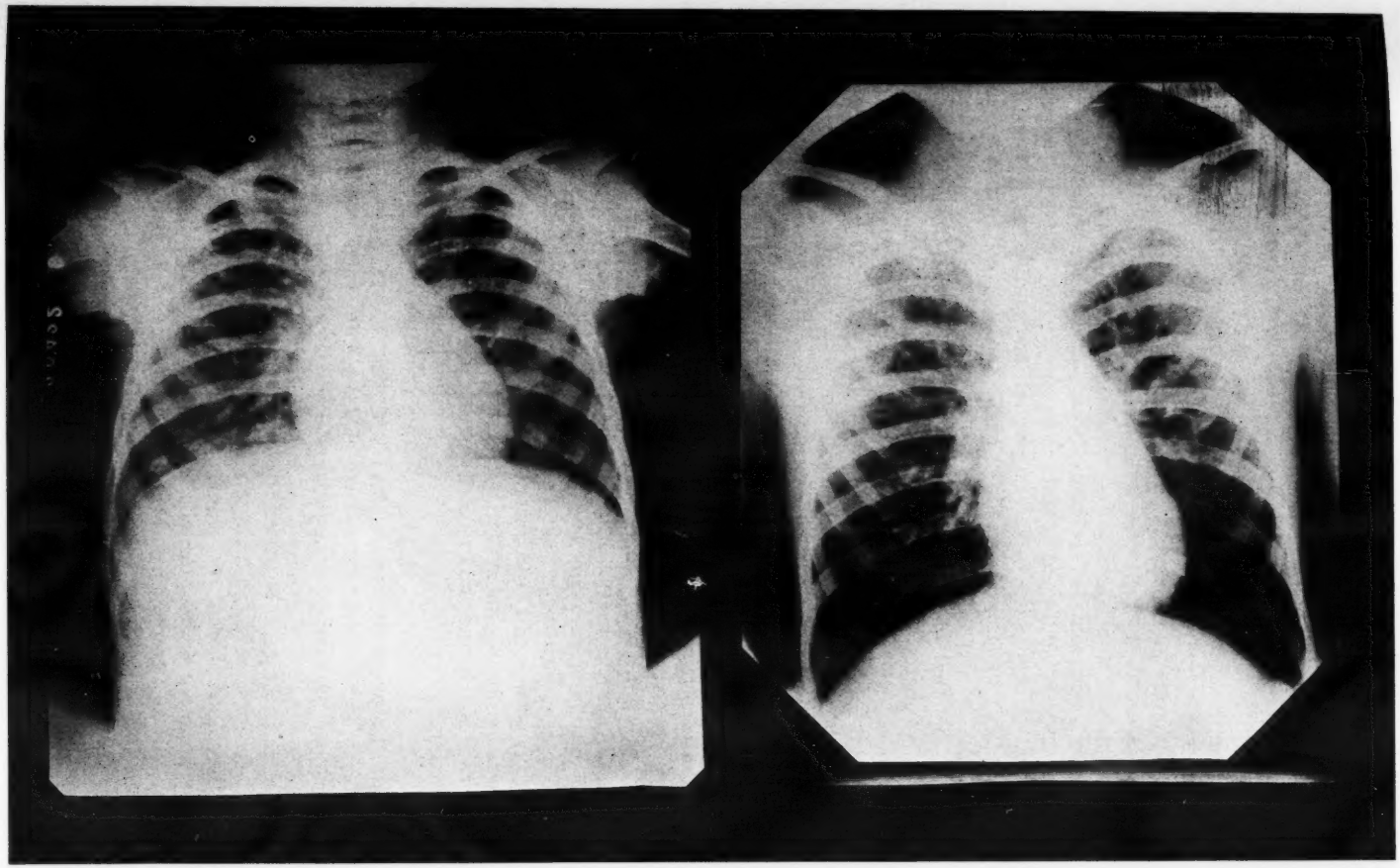

Fig. 4. *Diseased Chest.* Enlargements of 3- and 10-year roentgenograms as shown in Figure 2. Study with the hand lens shows increased peribronchial and perivascular markings characteristic of bronchosinusitis disease. The chest disease is apparent on the first film and extends throughout the series. Compare with Figure 3.

show no chest changes are all in the second age group. However, since the age of two of these cases is three years and of the other, three years and nine months, they are probably too young for positive diagnoses as yet. Further study is necessary to determine the outcome of these cases. In other words, may it not be too early to portray definitely on the roentgen film evidence of disease of the lungs in these cases?

Some relationship between the severity of the sinus disease and the chest changes is noted. If the sinus involvement is of sufficiently long standing, pathologic changes can be identified in the chest. It is possible that changes in the lungs are congestive in the beginning and that, as time goes on, they become fibrous tissue changes. Probably, also, if the chest disease is of too short duration, the chest changes are not recognized. Once this connective tissue change is established, the improvement in the sinus, acting as an indicator of respiratory infection, may mark a cessation of progress in the chest changes. However, the chest changes do not undergo resolution but remain as permanent markings of the lungs. It is to be noted that decreased aeration of the sinuses (sometimes referred to as increased density) is more readily recognized by the eye than the minute inflammatory changes along the bronchi and the vascular markings of the lungs.

ROENTGENOLOGIC FINDINGS OF THE CHESTS SHOWING DISEASE IN ASSOCIATION WITH SINUS DISEASE

It is not the purpose of this paper to give a detailed description of the roentgen findings of the non-tuberculous chest. In general, we have considered the characteristic changes to be a bilateral increase in width and density of the hila, together with accentuation of the perivascular and peribronchial markings. In some cases of early disease the only findings appear to be a thickening of the hila, but as these cases progress a gradual accentuation of the trunk and linear markings appears to extend outward from the hila. Only in those advanced cases, as seen in our special series has the parenchymal tissue appeared to be involved, as evidenced by increased interstitial connective tissue changes.

DIFFERENTIAL DIAGNOSIS

The differentiation of the non-tuberculous disease in children is principally concerned with incipient tuberculous infection and irritation from dust inhalation (17). This does not take into consideration those non-tuberculous conditions such as abscesses, foreign bodies, and the acute conditions which show a typical pneumonia or parenchymal involvement. The factor of dust inhalation may be considered of minor importance, since the children reported in this group all live in Denver where gas is the chief fuel and the air is not heavily laden with dust. Incipient tuberculous infection originating near the hilum may be confusing, yet it tends to be unilateral and the primary focus may be evident, or, later in the course of the disease, some calcification may be demonstrated which is not shown in the non-tuberculous infection. The usual criteria for roentgen diagnosis of a tuberculous lesion in infancy are used. However, the greatest help is obtained from serial examinations over a period of years so that the character of a particular lesion may be established. A tuberculin reaction is helpful, but in one case which showed a positive tuberculin reaction the chest was studied for eight years and the changes were of the non-tuberculous type. In our series, there are two cases of healed tuberculosis, with superimposed chest changes and marked sinus disease, but five others of non-active tuberculosis show no superimposed chest changes.

The onset of the non-tuberculous chest condition or sinus disease in infants appears to be highly insidious. At what time the condition is first manifested is not yet definitely established but it is

probably in early infancy. Under two years of age, the presence of infection of the respiratory tract is much more common in a sub-acute form than is generally believed. From our series it would appear that the process may begin very early in infancy, long before the condition is usually diagnosed by clinical methods. By the time the respiratory infection has progressed to the point at which it produces definite clinical signs and symptoms, the child is usually several years old.

By the study of a larger series of cases and by similar series followed in other cities, it should be possible to gain most valuable information concerning this group of non-tuberculous chest diseases. Tuberculosis is now well controlled by scientific investigation and education, yet such methods of study and education have not been so well applied to the non-tuberculous respiratory infections. As a result, the latter are now of perhaps greater importance than the tuberculous infections and probably handicap a greater number of our population. That this is an important disease entity is apparent when, on analysis of Table III, it is seen that, out of 57 cases, five show non-active tuberculosis, whereas 30 cases show chest and sinus disease. Again it must be noted, however, that this is too small a group from which to draw far-reaching conclusions.

Two cases are presented to illustrate the above discussion.

Case 1. R. L., male, 10 years of age, was born at the National Jewish Hospital for Tuberculosis. Both parents had active tuberculosis at time of the birth of the patient. Father died of tuberculosis five years later. Patient had usual childhood diseases, frequent upper respiratory infections, and chronic otitis media. He had a positive tuberculin reaction and was 12 pounds underweight.

ROENTGENOLOGIC FINDINGS

Sinuses.—Since one year of age the patient had had chronic or recurrent sinus disease with exacerbations.

Chest.—Bilateral increased width and density of the hila, with accentuation of the peribronchial and perivascular markings. No evidence of pulmonary tuberculosis on any examination.

DIAGNOSIS

Clinical.—Frequent upper respiratory infections and otitis media.

Roentgen.—Sinus disease and non-tuberculous chest disease.

Case 2. T. I., male, 6 years of age. Family history negative except for frequent headaches and rheumatism (?). Patient has had the usual childhood diseases and frequent upper respiratory infections. There was a negative tuberculin reaction on two occasions; frequent post-nasal discharge. He was poorly nourished and 6 pounds underweight.

ROENTGENOLOGIC FINDINGS

Sinuses.—Many examinations, beginning at one year of age, show bilateral chronic or recurrent sinus disease.

Chest.—Bilateral increased density and width of the hila, with accentuation of the perivascular and peribronchial markings, beginning at 2 years 6 months.

DIAGNOSIS

Clinical.—Frequent upper respiratory infections. Underweight. Poorly nourished.

Roentgen.—Sinus disease and non-tuberculous chest disease.

SUMMARY

A report is presented of a study of the roentgen findings in the sinuses and chests of: (1) 100 children followed periodically since birth; (2) a "special group" of 58 children showing definite clinical evidence of infection, and (3) information drawn from material observed in private practice and at the Children's Hospital (Denver).

CONCLUSIONS

While we do not wish to draw too many or too general conclusions from the series of children which form the chief source of material for this report, neither do we think that those drawn from large groups of single examinations are tenable. Therefore, there are certain probable conclusions which our study suggests.

Our findings would seem to indicate that there is a relationship between sinus disease and non-tuberculous chest disease.

Inasmuch as this relationship seems to exist, the term "bronchosinusitis" has been used by one of us (W. W. W.) in previous articles to differentiate this type of condition from other acute and subacute general respiratory infections.

There are probably four main factors in the relationship between sinus disease and non-tuberculous chest disease.

(1) It seems likely that the onset in both *locales* is approximately coincidental, and the progress in each parallels that in the other.

(2) This chest and sinus disease appears to have an insidious onset, to be of long duration, and to show chronologic progressive changes.

(3) Increased severity of the condition in one region is associated with increased severity of the condition in the other.

(4) Cessation of sinus disease is usually accompanied by cessation of progress of non-tuberculous chest disease. This last does not necessarily mean that improvement of the sinus condition removes the causative agent for the chest infection, as the mode of extension has not yet been demonstrated.

From the above conclusions suggested from our study, we feel that further investigation of these complex factors is advisable.

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STANDARD ABSORPTION CURVES FOR SPECIFYING THE QUALITY OF X-RADIATION[1]

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ABSTRACT

In the measurement of x-rays there is a proportionality between the energy in the beam and its strength in roentgens, only for radiation of the same effective spectral distribution. In previous work, comparison with the copper and aluminum absorption curves produced by constant potential has been established as a means of equating the qualities of x-ray beams excited by various voltage wave forms. Therefore, a set of standard absorption curves is set up for copper up to 180 K.V. (constant) and aluminum up to 110 K.V. (constant). Accurate evaluation of the wall absorption of the tubes used permits the establishment of basic absorption curves. Similar curves are given for potentials from 250 to 550 K.V. (constant), using a tube having 6 mm. of copper filtration. The effect of wall absorption on the relative position of the absorption curves is discussed, and it is shown how a single curve may be used for a complete and adequate specification of x-ray quality. This may be contrasted with all other quality specifications, none of which is adequate without auxiliary information.

I.—INTRODUCTION

NUMEROUS investigations during the past years have stressed the need for a more adequate filtration method of determining the quality of x-ray beams that are excited by different potential wave forms. It is not that the methods in use—such as the half value layer—are theoretically unsound, but rather that, given alone, they are insufficient to give satisfactory correlation between radiations excited by potentials of different wave form. Furthermore, the several different methods in vogue do not express the quality of radiation in comparable terms.

It is, of course, well recognized that while the quality of an x-ray beam is given accurately only by the spectral energy distribution of the radiation, it is unfortunately impractical for common use. Accordingly various indirect methods of quality description have been based upon the absorption properties of some metal such as copper or aluminum for the radiation in question. Since an x-ray spectrum is a function of the potential, these methods are frequently complicated by the fact that the potential used for exciting the x-rays is periodically fluctuating. The "simple spectrum" is one produced by, and a function of, the instantaneous or sustained value of the exciting voltage and the target material. On the other hand, a "composite spectrum" is the resultant of the succession of instantaneous spectra produced by a periodically fluctuating potential and is, therefore, also a function of the wave form. Since the voltage wave forms applied to x-ray tubes are exceedingly varied and complicated, it is obvious that there is no direct simple relationship between the resultant composite spectra and the peak value of the exciting voltage. The absorption curve for radiation having a composite spectrum will be referred to as a "composite absorption curve" to distinguish it from the "simple absorption curve" characteristic of x-rays produced by constant potential.

Prime requisites for a satisfactory quality specification are, therefore: (1) a sound theoretical relationship between observed magnitudes and the spectral distribution of the radiation, and (2) a simple method of quality correlation which is reasonably independent of the exciting voltage wave form, *i.e.*, a correlation between the quality of some one simple spectral distribution and that of the given composite spectral distribution. Simplicity and convenience of operation naturally dictate the choice of method only after these two requirements are satisfied.

Of the customary quality specifica-

[1] Presented at the First American Congress of Radiology, at Chicago, Sept. 25–30, 1933.

tions—(1) complete absorption curve,[2,3] (2) half value layer,[4] (3) effective wave length,[5,6] and (4) average wave length[7]—Duane's effective wave length method, requiring but two measurements, is the most convenient. This simplicity is offset, however, by the indefiniteness of the final result.[8] The half value layer method has a slight advantage in simplicity over the remaining methods in that it requires fewer auxiliary computations. A theoretically definite conclusion, however, is obtained only from the complete absorption curve, the others requiring further information which can be obtained only from the complete absorption curve. That the complete absorption curve method is not only adequate but has advantages not possessed by any of the others has been shown by a number of workers.[9] For example, Silberstein has shown[10] theoretically that a given x-ray spectral distribution will yield a particular copper absorption curve; and conversely, a spectral distribution which is sufficiently accurate for practical purposes may be derived from the complete copper absorption curve.

Until recently the complete copper absorption curve method has had the disadvantage of not being expressible by a single numerical magnitude. This has been removed, however, by finding that, within reasonably satisfactory limits, the complete composite absorption curve of radiation excited by the different potential wave forms in use, may be matched by the instantaneous absorption curve of the same material for radiation excited by some definite constant potential.[9] It is further found[11] that such beams having equivalent absorption curves are, over a considerable range of initial filtration, closely alike as regards their intensity distribution in a large body of low atomic number material such as a water phantom. Since the spectral distribution of radiation excited by constant potential is perfectly reproducible, a family of simple absorption curves of constant voltage radiation should constitute a very convenient and adequate standard of reference for inferring the constant potential equivalent of any given radiation.[12]

It is of course obvious that two equivalent x-ray beams might be produced by voltages of very different peak values and hence one beam have shorter wave lengths not present at all in the other. However, the proved equivalence, where the peak voltages are very different, signifies that while there are some shorter wave lengths in one spectrum than in the other, they are present to a negligible extent.[13] As the equivalent constant voltage approaches the peak voltage it signifies that the energy in the shorter wave lengths becomes relatively greater. This, however, is taken care of in the specification of quality by the fact that for a given peak voltage, if the shorter wave lengths gain in importance, the equivalent voltage is correspondingly increased. For example, with x-rays produced respectively by mechanical, full wave, or Villard rectifiers operated at the same peak values, the equivalent voltage approaches respectively nearer the peak value, indicating an increasing relative

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[9] L. S. Taylor, G. Singer, and C. F. Stoneburner. Bureau of Standards Jour. Research (R. P. 592), 1933, XI, 293. See also Footnotes 2 and 3.

[10] L. Silberstein. Phil. Mag., Ser. 7, 1933, XV, 375.

[11] L. S. Taylor and K. L. Tucker. Bureau of Standards Jour. Research (R. P. 475), 1932, IX, 333.

[12] By "constant potential equivalent" is meant the constant potential necessary to apply to an x-ray tube to yield a simple absorption curve of the same form as the composite absorption curve in the same material for the unknown radiation in question.

[13] L. S. Taylor, G. Singer, and C. F. Stoneburner. Bureau of Standards Jour. Research (R. P. 592), 1933, XI, 293. In particular, see curves in Figures 8 and 9 of this paper.

TABLE I.—ABSORPTION OF GENERAL X-RADIATION IN COPPER

Tube wall, 1.29 mm. cerium glass

I_0 = Incident radiation I = Transmitted radiation 100 I/I_0 = Percentage Transmission

Copper Filter	100 K.V.		110 K.V.		120 K.V.		130 K.V.		140 K.V.		150 K.V.	
	100 I/I_0	Log 100 I/I_0	100 I/I_0	Log 100 I/I_0	100 I/I_0	Log 100 I/I_0	100 I/I_0	Log 100 I/I_0	100 I/I_0	Log 100 I/I_0	100 I/I_0	Log 100 I/I_0
(mm.)												
0	100	2.00	100	2.00	100	2.00	100	2.00	100	2.00	100	2.00
0.14	20.4_0	1.310	22.0_8	1.344	23.8_0	1.377	25.8_2	1.412	27.6_5	1.442	30.3_5	1.482
.20	15.3_9	1.187	17.8_4	1.251	19.9_2	1.299	21.8_1	1.339	23.4_2	1.370	25.6_8	1.410
.25	12.8_9	1.110	15.1_8	1.181	17.3_7	1.240	19.1_9	1.283	20.8_5	1.319	22.8_5	1.359
.30	11.1_5	1.047	13.1_7	1.120	15.2_3	1.183	17.0_0	1.230	18.7_1	1.267	20.5_5	1.313
.40	8.78	0.943	10.2_8	1.012	12.1_2	1.084	13.7_5	1.138	15.3_7	1.187	16.9_8	1.230
.50	7.15	0.854	8.50	0.924	10.0_5	1.002	11.5_7	1.063	13.0_6	1.116	14.4_2	1.159
.75	4.53	0.656	5.77	0.761	7.04	0.848	8.32	0.920	9.55	0.980	10.6_8	1.029
1.00	3.08	0.489	4.13	0.616	5.18	0.714	6.35	0.803	7.41	0.870	8.43	0.926
1.50	1.77	0.248	2.42	0.384	3.13	0.496	4.00	0.602	4.86	0.687	5.75	0.760
2.00	1.03	0.013	1.60	0.210	2.06	0.314	2.73	0.436	3.38	0.529	4.13	0.616
2.50	....	...	1.02	0.009	1.46	0.164	2.00	0.301	2.50	0.398	3.12	0.494
3.00	....	...	....	...	1.09	0.037	1.48	0.170	1.93	0.286	2.49	0.396

intensity of the shorter wave lengths. Correspondingly it is found that the absorption curves indicate respectively harder composite radiations after the same initial filtration.

It is also to be expected that two beams which yield like absorption curves with a low or moderate initial filtration (up to 1.5 mm. Cu at 150 K.V., constant) may after a higher initial filtration furnish somewhat divergent curves—the curve for the radiation having the higher peak voltage falling above the other. By matching the curves above the point corresponding to the initial filtration, however, a new equivalent voltage may be found which specifies the radiation more closely. This is perfectly justifiable, since the radiation not passing through the filter is lost.

This specification of x-ray quality, by using the complete absorption curve, has been recommended by the X-ray Standardization Committee of the Radiological Society of North America.[14]

[14] Quotation from Par. 7 of the 1933 Committee report: "For most practical purposes the quality of the x-radiation may be satisfactorily specified in terms of the copper or aluminum absorption curve combined with a statement of the initial filtration. In lieu of an absorption curve, the equivalent constant potential applied to the tube terminals to yield the same curve may be stated as a single numerical magnitude. Up to 100 K.V. (constant) aluminum absorption curves and above 100 K.V. (constant) copper absorption curves shall be used to establish the equivalent potential." RADIOLOGY, March, 1934, XXII, 289.

The main purpose, then, of the present investigation was to lay a general foundation and develop a procedure for deriving the two parameters of any absorption curve, namely, the equivalent constant potential excitation, together with the equivalent initial absorption.

II.—EXPERIMENTAL PROCEDURE AND CORRELATION OF ABSORPTION CURVES

The standard absorption curves shown here were obtained under conditions believed to be adequate for the purpose at the present time. The irradiation[15] was measured in roentgens per minute by means of a standard guarded field ionization chamber. The ionization current was measured by a null method,[16] using an electrometer and compensating system previously described. The readings were accurate within ± 0.3 per cent. Voltages applied to the tube were supplied by a kenotron rectifier of the Hull-Webster type, in which at the tube currents used the ripplage did not exceed 1 per cent.

[15] The term "irradiation" is used to emphasize the fact that these measurements were made in terms of the ionization produced in air. The ionization measurements can be used for "intensity" only when dealing with x-ray beams of exactly the same spectral distribution, and not with beams of different distribution.

[16] L. S. Taylor. Bureau of Standards Jour. Research (R. P. 306), 1931, VI, 807.

TABLE II.—ABSORPTION OF GENERAL X-RADIATION IN COPPER

Tube wall, 4.78 mm. pyrex glass

I_0 = Incident radiation I = Transmitted radiation $100\ I/I_0$ = Percentage transmission

Copper Filter	100 K.V.		110 K.V.		120 K.V.		130 K.V.		140 K.V.		150 K.V.		160 K.V.		170 K.V.		180 K.V.	
	$100\ I/I_0$	Log $100\ I/I_0$	$100\ I/I_0$	Log $100\ I/I_0$	$100\ I/I_0$	Log $100\ I/I_0$	$100\ I/I_0$	Log $100\ I/I_0$	$100\ I/I_0$	Log $100\ I/I_0$	$100\ I/I_0$	Log $100\ I/I_0$	$100\ I/I_0$	Log $100\ I/I_0$	$100\ I/I_0$	Log $100\ I/I_0$	$100\ I/I_0$	Log $100\ I/I_0$
(mm.)																		
0	100	2.00	100	2.00	100	2.00	100	2.00	100	2.00	100	2.00	100	2.00	100	2.00	100	2.00
0.14	44.3_0	1.646	46.2_8	1.665	49.6_0	1.695	52.1_5	1.717	54.2_0	1.734	55.6_8	1.745	56.6_8	1.753	57.9_8	1.763	59.5_8	1.775
.20	34.5_9	1.539	37.0_0	1.568	40.7_2	1.610	43.9_0	1.642	45.2_6	1.656	47.2_0	1.674	49.0_0	1.690	51.1_0	1.708	52.8_8	1.723
.25	29.8_8	1.475	32.3_9	1.510	36.0_0	1.558	39.0_8	1.592	40.5_0	1.607	42.7_0	1.630	44.4_4	1.648	46.7_5	1.670	48.1_8	1.683
.30	25.8_0	1.411	28.6_2	1.457	32.3_5	1.510	34.0_0	1.531	36.9_2	1.567	38.6_5	1.587	40.6_0	1.609	42.8_8	1.632	43.9_8	1.643
.40	20.3_5	1.309	23.1_8	1.365	26.5_8	1.424	29.2_0	1.465	31.5_5	1.499	33.2_8	1.522	34.9_5	1.543	36.7_6	1.565	38.8_7	1.590
.50	16.3_7	1.214	18.9_5	1.278	21.8_2	1.339	24.3_4	1.387	26.7_7	1.428	29.3_0	1.467	30.1_7	1.480	32.1_5	1.507	23.8_8	1.530
.75	11.6_0	1.064	13.9_2	1.144	15.8_2	1.199	18.2_8	1.262	20.4_1	1.310	22.4_0	1.350	24.0_4	1.381	26.0_1	1.416	27.7_2	1.443
1.00	8.27	0.918	10.2_7	1.012	11.9_8	1.078	14.0_6	1.148	16.0_2	1.205	17.8_8	1.252	19.5_6	1.291	21.2_2	1.327	22.7_8	1.358
1.50	4.44	0.647	6.02	0.780	7.68	0.885	9.28	0.968	10.8_2	1.034	12.2_8	1.089	13.8_6	1.141	15.2_2	1.182	16.4_9	1.217
2.00	2.60	0.415	3.89	0.590	5.17	0.714	6.53	0.815	7.78	0.891	9.02	0.955	10.1_8	1.008	11.4_3	1.058	12.6_8	1.103
2.50	....	....	....	....	3.55	0.550	4.67	0.669	5.87	0.769	6.84	0.835	7.88	0.897	8.83	0.946	9.95	0.997
3.00	....	....	....	....	2.57	0.410	3.61	0.558	4.64	0.667	5.54	0.744	6.48	0.812	7.36	0.867	8.35	0.921

The average tube voltage was measured by means of a shielded high resistance voltmeter connected directly across the tube terminals.[17] The voltages given are all average values and hence peak values are about 0.3 to 0.5 per cent higher. Since the average voltage has been shown to provide a better indication than peak voltage of the tube output on voltages of different ripplage,[18] the uncertainty of 0.2 per cent in the peak value is of no consequence. During observations the tube voltage was measured and kept constant within limits of about 0.15 per cent.

The x-ray tubes employed were housed in a lead box $4 \times 4 \times 7$ feet. To provide steadiness of operation the filament was heated by a storage battery, and the high voltage source supplied through a power stabilizer. Fluctuation in voltage was very slow, corresponding to, and caused by, the change in power line frequency; and, since it was seldom greater than about ± 0.3 per cent, was easily compensated manually.

The filters were located for convenience about 50 cm. from the target and 60 cm. from the entrant diaphragm on the chamber. This precluded the possibility of a measurable amount of scattered radiation entering the chamber. To further insure this, the beam was diaphragmed down to a diameter of about 4 cm. at the filters.

Two types of tungsten target tube were used for the measurements—a hard glass thick-walled type for the higher excitation potentials and a soft glass thin-walled type for the lower. This corresponds approximately to the voltage ranges in which such tubes are used in practice. Since absorption of radiation by the walls is very different between such tubes, it is necessary that it be taken into consideration. Of a number of thick pyrex tubes available we chose for the final measurements one 4.8 mm. thick, about the average of the group.

Table I gives the copper absorption

[17] L. S. Taylor. Bureau of Standards Jour. Research (R. P. 217), 1930, V, 609.

[18] L. S. Taylor, G. Singer, and C. F. Stoneburner. Bureau of Standards Jour. Research (R. P. 491), 1932, IX, 561.

values for radiation from a thin tube (in which the wall absorption is about the same as for 0.02 mm. of copper). In the first column are given filter thicknesses at selected intervals. In the other double columns headed by the applied tube voltage are given, respectively, the percentage transmission of the filter and its corresponding logarithm to the base 10. Where, in making the measurements, the filter thickness or applied voltage deviated appreciably from the given rounded values, corrections were applied to obtain the desired values.

Similar data for the thick pyrex tube (having a wall absorption about the same as 0.1 mm. of copper) is given in Table II. Below 100 K.V. (constant), absorption in aluminum has been recommended as a standard, hence Table III gives aluminum absorption data. In making these measurements, the same thin glass tube as for Table I was used.

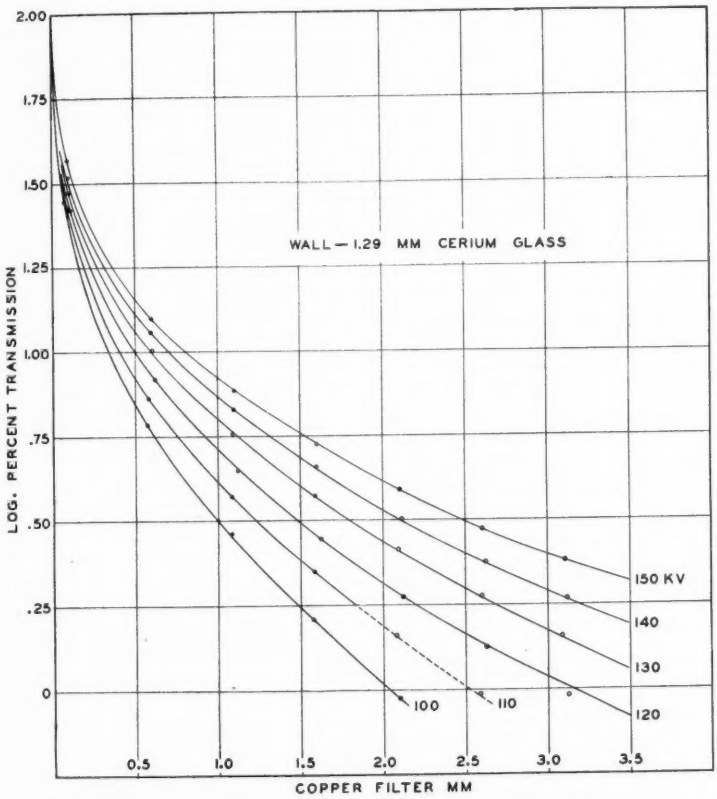

Fig. 1. Copper absorption curves for thin glass tube (solid line). Plotted circles are not for the curves shown but are taken from Figure 2 and superposed to show matching by the proper shifting of each curve.

Figures 1, 2, and 3 give, respectively, for various constant potential excitations, the semilogarithmic absorption curves for copper and aluminum as plotted from Tables I, II, or III, respectively. If it is assumed that, for the same excitation potential, the spectral distribution of the radiation emitted by the anticathodes of the two tubes is the same, then the difference between the

TABLE III.—ABSORPTION OF GENERAL X-RADIATION IN ALUMINUM

Tube wall, 1.29 mm. cerium glass

I_0 = Incident radiation I = Transmitted radiation $100\,I/I_0$ = Percentage transmission

Copper Filter	60 K.V.		70 K.V.		80 K.V.		90 K.V.		100 K.V.		110 K.V.	
	$100\,I/I_0$	Log $100\,I/I_0$	$100\,I/I_0$	Log $100\,I/I_0$	$100\,I/I_0$	Log $100\,I/I_0$	$100\,I/I_0$	Log $100\,I/I_0$	$100\,I/I_0$	Log $100\,I/I_0$	$100\,I/I_0$	Log $100\,I/I_0$
(mm.)												
0	100	2.00	100	2.00	100	2.00	100	2.00	100	2.00	100	2.00
1	32.1	1.507	33.8_8	1.530	36.0_4	1.557	38.9_0	1.590	40.3_9	1.606	42.4_2	1.628
2	19.0	1.279	20.8_1	1.318	22.9_2	1.360	25.2_8	1.403	27.2_0	1.435	29.4_0	1.468
3	12.8_5	1.109	14.4_0	1.158	16.5_2	1.218	18.4_2	1.265	20.3_8	1.309	22.3_5	1.349
4	9.3_4	0.970	10.7_8	1.033	12.6_4	1.102	14.4_1	1.159	16.2_0	1.210	18.0_2	1.256
5	7.0_0	0.845	8.44	0.926	10.0_8	1.003	11.6_0	1.064	13.4_0	1.127	15.0_2	1.177
6	5.41	0.733	6.79	0.832	8.25	0.916	9.69	0.986	11.3_2	1.054	12.8_8	1.110
7	4.35	0.639	5.53	0.743	6.88	0.838	8.33	0.921	9.80	0.991	11.2_2	1.050
8	3.55	0.550	4.61	0.664	5.84	0.766	7.21	0.858	8.58	0.934	9.92	0.997
10	2.44	0.387	3.42	0.534	4.38	0.642	5.44	0.736	6.63	0.822	7.85	0.895
15	1.16	0.065	1.79	0.253	2.40	0.380	3.17	0.501	4.06	0.609	4.80	0.681
20			1.00	0.000	1.40	0.147	2.01	0.303	2.60	0.415	3.17	0.501

copper absorption curves corresponding to the same potential in Figures 1 and 2 arises entirely from the difference in the absorption of the two tube walls—1.3 mm. cerium glass and 4.8 mm. pyrex glass.

To bring out the general information to be inferred from the absorption curves of Figures 1 to 3, and from this to correlate the curves of Figure 2 with those of Figure 1, we will take a hypothetical absorption curve AB (Fig. 4) in which x gives the thickness of copper filter, and

$$y = \log (100 I/I_0) \qquad (1)$$

gives the corresponding values of log percentage transmission. Here we will also assume that the incident radiation I_0 is obtained from an ideal x-ray tube of zero wall thickness. In that case, AB is the basic absorption curve corresponding to the given excitation potential.

As a first case, we wish to show how, from this basic curve, the absorption curve is obtained for the same radiation after it has been modified in quality by traversing a given thickness, d, of the filter. In this case, I_d, the number of roentgens emerging from the thickness, d, becomes the incident radiation for the new curve. Against new thickness values,

$$x' = x - d \qquad (2)$$

of the filter, are plotted new log percentage transmissions,

$$y' = \log \left(100 \frac{I}{I_d}\right)$$

$$= \log \left(100 \frac{\frac{100 I}{I_0}}{\frac{100 I_d}{I_0}}\right)$$

$$= \log \left(100 \frac{I}{I_0}\right) + \log \left(\frac{100}{100 \frac{I_d}{I_0}}\right)$$

$$= y + 2 - \log \left(100 \frac{I_d}{I_0}\right) \qquad (3)$$

$$= y + \text{constant}.$$

Thus all points on the new curve differ in position from corresponding ones on the basic curve by the same amount; that is, the new curve is obtained from the basic curve by merely shifting the origin of co-ordinates to the point $x = d$ and $y = -\left(2 - \log 100 \frac{I_d}{I_0}\right)$. That this conclusion is true may be shown by the following analysis. The 100 per cent transmission point ($y' = 2$) of the new curve must lie directly above the point $x = d$ on the basic curve; this is C in Figure 4. By assigning y' this value in Eq. 3

TABLE IV.—ABSORPTION OF GENERAL X-RADIATION IN COPPER

Initial filtration: Tube wall, 1.29 mm. cerium glass and 0.25 mm. copper

I_0 = Incident radiation I = Transmitted radiation $100\,I/I_0$ = Percentage transmission

Copper Filter	100 K.V.		110 K.V.		120 K.V.		130 K.V.		140 K.V.		150 K.V.	
	$100\,I/I_0$	Log $100\,I/I_0$	$100\,I/I_0$	Log $100\,I/I_0$	$100\,I/I_0$	Log $100\,I/I_0$	$100\,I/I_0$	Log $100\,I/I_0$	$100\,I/I_0$	Log $100\,I/I_0$	$100\,I/I_0$	Log $100\,I/I_0$
(mm.)												
0	100	2.00	100	2.00	100	2.00	100	2.00	100	2.00	100	2.00
0.15	66.5	1.823	67.3	1.828	69.8	1.844	71.8	1.856	73.5	1.866	74.5	1.872
.25	53.7	1.730	56.2	1.750	58.5	1.767	61.0	1.785	62.4	1.795	63.8	1.805
.5	34.2	1.534	38.0	1.580	40.7	1.609	43.7	1.640	45.7	1.660	47.1	1.673
.75	23.9	1.378	27.2	1.435	29.8	1.475	33.1	1.520	35.5	1.551	36.9	1.567
1.25	13.7	1.138	15.9	1.203	18.0	1.256	20.9	1.319	23.3	1.368	25.2	1.401
1.75	8.00	0.903	10.1	1.005	11.9	1.074	14.2	1.154	16.2	1.210	18.1	1.257
2.25	....	...	6.70	0.826	8.40	0.924	10.4	1.018	12.00	1.078	13.7	1.136
2.75	....	...	....	...	6.11	0.786	7.72	0.887	9.25	0.966	10.9	1.037

$$y = \log 100\,\frac{I_d}{I_0}$$

which is, compared with Eq. 1, the log percentage transmission on the basic curve for a thickness $x = d$ of the filter. This is consistent with the imposed condition that I_d should be considered the incident radiation for this particular case. If, then, we have the data for the basic absorption curve—no initial filtration—corresponding data for the radiation, after being subjected to any given initial filtration, are readily obtained by reducing the observed filter thicknesses by the initial thickness, d, and by increasing all observed log percentage transmissions by $2 - \log\left(100\,\frac{I_d}{I_0}\right)$.

The second case deals with the converse problem: given two absorption curves of the same radiation, but subjected to different amounts of filtration; to find the difference in thickness of the initial filters. Here we are supposed to have two separate absorption curves of Figure 4—AB on the xy axes; and CB plotted (on transparent paper) on the $x'y'$ axes. The second is laid over the first and shifted to that position where it is found to fit the first. The difference, d, in the two filter thicknesses, for corresponding points on the two curves, is given by the difference $(x - x')$ for the point C and is the magnitude sought.

Having outlined the general procedure we shall next inquire if like excitation potentials in the two tubes of Figures 1 and 2 produce absorption curves which are subject to the same correlation as curves CB and AB (Fig. 4) just treated. In other words: is the radiation from the thick wall pyrex tube (of Fig. 2) of the same quality as that from the thin wall tube (of Fig. 1) after passing through some unknown thickness of copper?

By taking curves of Figure 2, and fitting them, as just described, to the curves of like excitation potential in Figure 1, a very satisfactory correlation is obtained. The plotted points on the curves in Figure 1 are from the corresponding curves of Figure 2—each point on the extreme left indicating the thickness of copper (about 0.1 mm.) which would make up the difference in effect of the walls of the two tubes. As may be expected, this thickness varies somewhat with the excitation potential, because the spectral absorption in glass is not the same as in copper.

From the consistency of this correlation—in which it is obvious that absorption curves corresponding to different excitation potentials do not fit—it is to be concluded that the shape of the absorption curve is characteristic of the excitation potential. On the other hand, the coordinate displacement of the given curve from that of the basic curve is characteristic of the filtration between the target and the point of measurement. Having a

family of such curves (as in Fig. 1), in which the constant excitation potential varies by steps of practicable magnitude, it is clear that instead of using the complete absorption curve to specify the quality of the radiation, we may use the more convenient magnitudes: excitation potential (constant) and initial filtration. Since, as shown in an earlier publication, the radiation excited by various potential wave forms, may be simply and adequately equated to that of some equivalent constant potential excitation, the quality of any given radiation may be specified by *its equivalent constant excitation potential and the initial filtration.* This initial filtration is desirably expressed in terms of the equivalent copper or aluminum.

III.—EQUIVALENT THICKNESS OF TUBE WALLS

This section is for the twofold purpose of revealing the degree of consistency obtainable from the foregoing conclusion; and of providing data from which an operator may evaluate the absorption in the wall of his own x-ray tube.

It should, of course, be borne in mind that because of the difference in atomic numbers of glass, aluminum, and copper, the equivalent thickness of one in terms of any other varies with the excitation potential of the radiation. By equivalent thickness of the tube wall, therefore, is meant the thickness of copper or aluminum which will reduce the given incident radiation by the same fraction of its initial value as does the tube wall.

As will be seen, the equivalent thickness is not proportional to the thickness of the material. Then too, two different materials of the same equivalent thickness do not necessarily change the quality of the beam to the same degree; the change in quality varies with the exciting potential and the thickness of the absorber. However, for conditions ordinarily encountered in practice the quality change produced by equivalent thicknesses of glass, aluminum, and copper is not very different and, therefore, as we shall do below, may usually be neglected. Thus tube wall absorption may be considered as a special example of the general case set forth in Figure 4 where the wall absorption corresponds to the initial filtration, d, for the curve CB. Upon the experimental determination of $\log\left(100\,\frac{I_d}{I_0}\right)$ it is thus possible by the methods already discussed to set up the basic absorption curve for filter thickness greater than d—but not less.

Tables IV to X, inclusive, give absorption data for various tube walls, together with the commonly used filters of copper and aluminum.

Samples used for obtaining absorption data (Tables XI and XII) of tube walls were in part cut from old tubes and in part from unused plane plates of lime and pyrex glass. The thickness of the curved pieces was measured by a spherical micrometer.

TABLE V.—ABSORPTION OF GENERAL X-RADIATION IN COPPER

Initial filtration: Tube wall, 1.29 mm. cerium glass and 0.5 mm. copper

I_0 = Incident radiation I = Transmitted radiation $100\,I/I_0$ = Percentage transmission

Copper Filter	100 K.V.		110 K.V.		120 K.V.		130 K.V.		140 K.V.		150 K.V.	
	$\frac{100}{I/I_0}$	$\frac{\text{Log } 100}{I/I_0}$	$\frac{100}{I/I_0}$	$\frac{\text{Log } 100}{I/I_0}$	$\frac{100}{I/I_0}$	$\frac{\text{Log } 100}{I/I_0}$	$\frac{100}{I/I_0}$	$\frac{\text{Log } 100}{I/I_0}$	$\frac{100}{I/I_0}$	$\frac{\text{Log } 100}{I/I_0}$	$\frac{100}{I/I_0}$	$\frac{\text{Log } 100}{I/I_0}$
(mm.)												
0	100	2.00	100	2.00	100	2.00	100	2.00	100	2.00	100	2.00
0.25	63.8	1.805	67.6	1.830	70.2	1.846	71.8	1.856	73.3	1.865	74.6	1.873
0.50	44.3	1.646	48.7	1.688	51.6	1.712	54.9	1.739	56.8	1.754	58.5	1.767
1.0	24.4	1.387	28.5	1.455	31.2	1.494	34.6	1.539	37.2	1.571	39.9	1.601
1.5	14.6	1.165	18.1	1.257	20.5	1.312	23.6	1.373	25.9	1.413	28.6	1.457
2.0	9.29	0.968	12.0	1.080	14.5	1.162	17.3	1.238	19.1	1.280	21.6	1.335
2.5	....	...	...	...	10.9	1.035	12.8	1.107	14.7	1.170	17.3	1.237

The wall thickness, D, of the x-ray tubes used was also measured—by the customary micrometer microscope method—focussing first on the outer surface markings, then on the inner surface markings, and observing the displacement, s, of the microscope between these two positions.[19] This displacement multiplied by the refractive index, n, of the glass gives its thickness. The index of refraction used for lime glass was 1.52 and that for pyrex 1.48.[20] These refractive indices were checked by thickness measurements, D, and displacement measurements, s, on pieces of the same kind from broken tubes, n being equal to D/s.

For determining the copper and aluminum absorption equivalents of pyrex glass above 100 K.V., Table XI, the radiation from the cerium glass tube of Figure 1 was used, being taken without wall correction as representing the unaltered anticathode radiation. This was considered permissible in that the copper equivalent of its wall could not be more than 0.02 mm.—one-sixth that found for the difference between this thin tube and the pyrex tube of Figure 2.

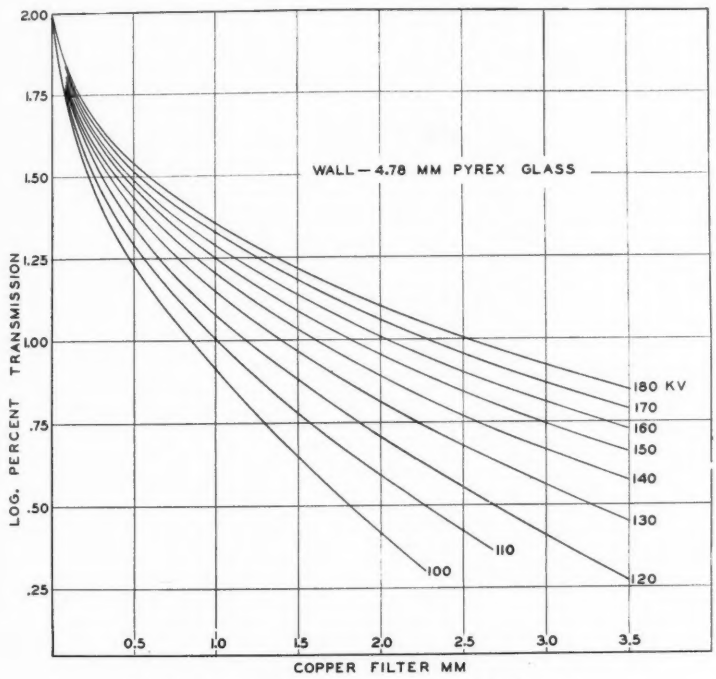

Fig. 2. Copper absorption curves for thick glass tube.

For determining the aluminum equivalents of lime glass, Table XII, a lime glass tube, 0.45 mm. thick, was used as source of radiation. The nearly linear relation between the thicknesses of glass and of aluminum which have the same absorption at the lower thicknesses permits a fairly accurate aluminum equivalent to be assigned to this tube wall.[21]

An examination of Tables XI and XII will show that the variation with exciting

[19] The surface markings are best seen under tangential illumination.

[20] Their respective densities were 2.54 and 2.24.

[21] There may be some question as to the validity of this assumption since the measurements were all made on a radiation initially filtered with 0.45 mm. of lime glass. If present at all, the error is small.

TABLE VI.—ABSORPTION OF GENERAL X-RADIATION IN COPPER

Initial filtration: Tube wall, 1.29 mm. pyrex glass and 0.25 mm. copper

I_0 = Incident radiation I = Transmitted radiation $100\,I/I_0$ = Percentage transmission

Copper Filter	100 K.V.		110 K.V.		120 K.V.		130 K.V.		140 K.V.		150 K.V.		160 K.V.		170 K.V.		180 K.V.	
	$100\ I/I_0$	Log $100\ I/I_0$	$100\ I/I_0$	Log $100\ I/I_0$	$100\ I/I_0$	Log $100\ I/I_0$	$100\ I/I_0$	Log $100\ I/I_0$	$100\ I/I_0$	Log $100\ I/I_0$	$100\ I/I_0$	Log $100\ I/I_0$	$100\ I/I_0$	Log $100\ I/I_0$	$100\ I/I_0$	Log $100\ I/I_0$	$100\ I/I_0$	Log $100\ I/I_0$
(mm.)																		
0	100	2.00	100	2.00	100	2.00	100	2.00	100	2.00	100	2.00	100	2.00	100	2.00	100	2.00
0.15	68.6	1.836	70.5	1.848	72.1	1.858	74.2	1.870	75.9	1.880	77.3	1.888	78.3	1.894	79.3	1.899	80.2	1.904
.25	57.3	1.758	59.6	1.775	61.7	1.790	63.5	1.803	66.1	1.820	67.9	1.832	68.9	1.838	70.0	1.845	71.4	1.854
.50	38.8	1.589	42.2	1.625	43.9	1.643	46.8	1.267	50.4	1.702	52.5	1.720	54.1	1.730	55.1	1.741	57.6	1.760
.75	27.7	1.442	31.3	1.495	33.3	1.522	35.9	1.556	39.6	1.597	41.9	1.622	44.0	1.643	45.4	1.657	47.3	1.675
1.25	14.9	1.172	18.6	1.269	21.3	1.330	23.7	1.376	26.7	1.426	28.8	1.459	31.3	1.496	32.6	1.513	34.2	1.534
1.75	8.70	0.940	12.00	1.079	14.4	1.157	16.7	1.223	19.2	1.284	21.1	1.325	22.9	1.360	24.4	1.388	26.3	1.420
2.25	....	...	7.96	0.900	9.87	0.994	11.9	1.076	14.5	1.161	16.0	1.205	17.7	1.249	19.3	1.285	21.3	1.328
2.75	....	...	....	...	7.14	0.854	9.24	0.966	11.5	1.059	13.0	1.113	14.6	1.164	15.8	1.197	17.3	1.239

TABLE VII.—ABSORPTION OF GENERAL X-RADIATION IN COPPER

Initial filtration: Tube wall, 4.78 mm. pyrex glass and 0.5 mm. copper

I_0 = Incident radiation I = Transmitted radiation $100\,I/I_0$ = Percentage transmission

Copper Filter	100 K.V.		110 K.V.		120 K.V.		130 K.V.		140 K.V.		150 K.V.		160 K.V.		170 K.V.		180 K.V.	
	$100\ I/I_0$	Log $100\ I/I_0$	$100\ I/I_0$	Log $100\ I/I_0$	$100\ I/I_0$	Log $100\ I/I_0$	$100\ I/I_0$	Log $100\ I/I_0$	$100\ I/I_0$	Log $100\ I/I_0$	$100\ I/I_0$	Log $100\ I/I_0$	$100\ I/I_0$	Log $100\ I/I_0$	$100\ I/I_0$	Log $100\ I/I_0$	$100\ I/I_0$	Log $100\ I/I_0$
(mm.)																		
0	100	2.00	100	2.00	100	2.00	100	2.00	100	2.00	100	2.00	100	2.00	100	2.00	100	2.00
0.25	70.2	1.846	71.5	1.854	73.3	1.865	75.0	1 875	76.6	1.844	78.5	1.895	79.6	1.901	80.9	1.908	82.0	1.914
.50	50.1	1.700	53.2	1.726	55 4	1.743	57.7	1.761	60.0	1.778	62.4	1.795	64.3	1.808	66.1	1.820	67.5	1.829
1.00	27.1	1.433	31.8	1.502	35.2	1.546	38.1	1.581	40.1	1.603	43.0	1.633	45.3	1.656	47.3	1.675	48.6	1.687
1.50	15.9	1.201	20.5	1.312	23.6	1.373	26.8	1.429	29.1	1.463	31.5	1.499	33.7	1.528	35.6	1.551	37.4	1.573
2.00	...	...	...	...	16.3	1.211	19.5	1.290	21.9	1.341	23.9	1.379	26.1	1.417	28.2	1.450	29.9	1.476
2.50	...	...	...	...	11.8	1.071	14.8	1.171	17.3	1.239	19.1	1.280	20.9	1.320	22.9	1.360	24.6	1.392

voltage of the equivalent copper or aluminum filtration of glass is not large and may be assumed as constant except for the most accurate work.

The consistency of these data on tube wall equivalents is strikingly illustrated in Figure 5 by the accuracy of the correlation which they furnish for the copper absorption curves of the radiation from five tubes differing both in construction and wall thickness, all excited by 150 K.V. (constant).

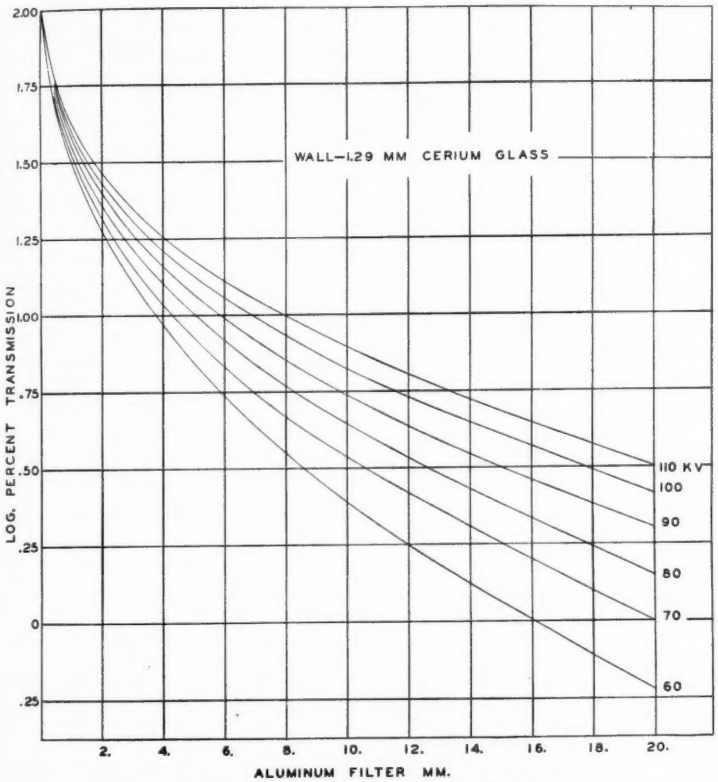

Fig. 3. Aluminum absorption curves for thin glass tube.

To be properly related, the data for these curves should be plotted, each on its proper co-ordinates, as fixed by the wall filtration. To avoid this multiplicity of co-ordinate systems, the data for the pyrex tubes (dashed lines) and the cerium tube (solid line) are plotted in the usual manner—taking as 100 per cent transmission, the radiation filtered only by the tube wall in each case. Finally, the data for all pyrex tubes are correlated with that of the cerium glass tube, following the procedure indicated by Equations 2 and 3 and taking into account here the copper equivalent of the cerium tube wall. All copper filtration values for the pyrex tube data are increased by the difference in the copper equivalents of the two tube walls—that of the cerium tube being estimated as 0.02 mm. of Cu. All log per cent transmissions for the radiation from the pyrex tube are accordingly decreased by the difference in the log per cent transmission of the corresponding copper equivalents of the walls—as given in Table I. This operation should bring the absorption curve for the given pyrex tube into coincidence with that of the cerium tube. This correlation is

indicated by the plotted points on the full line curve for the cerium tube of Figure 5.

The fit is very good, and shows with what assurance the quality of constant potential radiation from a tube of given

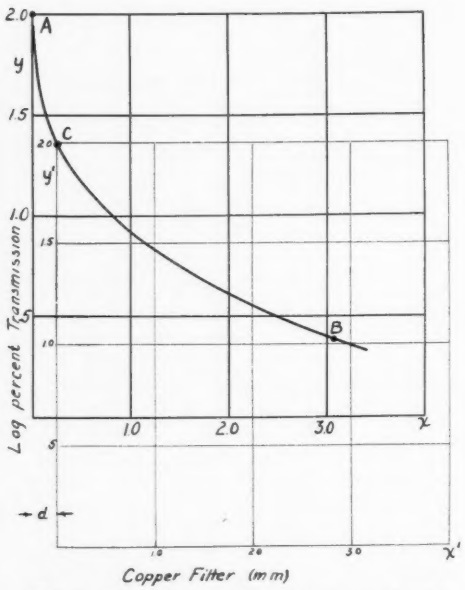

Fig. 4. Hypothetical absorption curve showing the shift of co-ordinates due to initial filtration.

wall thickness can be evaluated in terms of the constant potential excitation and equivalent filtration. In other words, the equivalent thickness of the tube wall constitutes a unique and adequate specification of the quality of radiation furnished by a given x-ray tube.

IV.—COPPER ABSORPTION CURVES ABOVE 250 K.V. EXCITATION POTENTIAL

The need for specifying the quality of x-rays excited by the so-called "ultra high voltages"—250 K.V. and above—is particularly accentuated at present when such radiations are fast coming into use. In case of such radiation in which the wave form of the excitation potential varying as it does from the extreme furnished by the induction coil up to that of very nearly constant magnitude, it is essential that their equivalence be fixed—perhaps most suitably in terms of constant potential. The first step is to obtain the absorption curves of radiation excited by the corresponding range of constant potentials. These data were obtained through the courtesy of Dr. Roscoe L. Smith, of Lincoln, Nebraska, who placed for this purpose his 800 K.V. constant potential set at our disposal.[22] With this set, in which the x-ray tube with a tungsten target had a wall of 6.4 mm. steel plus 13 mm. of water—this initial filtration being equivalent to about 6 mm. of copper—the determination of copper absorption curves in the range between 250 and 550 K.V. (constant) was carried out under as nearly

[22] We are greatly indebted to him and to Mr. T. R. Folsom for their cordial co-operation and assistance.

TABLE VIII.—ABSORPTION OF GENERAL X-RADIATION IN ALUMINUM

Initial filtration: Tube wall, 1.29 mm. cerium glass and 1.0 mm. aluminum

I_0 = Incident radiation I = Transmitted radiation $100\,I/I_0$ = Percentage transmission

Copper Filter	60 K.V.		70 K.V.		80 K.V.		90 K.V.		100 K.V.		110 K.V.	
	$100\,I/I_0$	Log $100\,I/I_0$	$100\,I/I_0$	Log $100\,I/I_0$	$100\,I/I_0$	Log $100\,I/I_0$	$100\,I/I_0$	Log $100\,I/I_0$	$100\,I/I_0$	Log $100\,I/I_0$	$100\,I/I_0$	Log $100\,I/I_0$
(mm.)												
0	100	2.00	100	2.00	100	2.00	100	2.00	100	2.00	100	2.00
1	59.2	1.772	61.5	1.789	63.6	1.803	64.9	1.813	67.4	1.829	69.3	1.841
2	40.0	1.602	42.5	1.629	45.8	1.661	47.3	1.675	50.4	1.703	52.6	1.721
3	29.1	1.464	31.8	1.503	35.1	1.545	37.0	1.569	40.1	1.603	42.5	1.628
4	21.8	1.338	24.9	1.397	28.0	1.447	29.8	1.475	33.2	1.521	35.4	1.549
5	16.8	1.226	20.4	1.310	22.9	1.360	24.9	1.397	28.0	1.448	30.3	1.482
6	13.5	1.131	16.3	1.213	19.1	1.281	21.4	1.331	24.3	1.385	26.4	1.422
7	11.1	1.043	13.6	1.134	16.2	1.210	18.5	1.268	21.2	1.327	23.4	1.369
9	7.59	0.880	10.1	1.004	12.2	1.085	14.0	1.146	16.4	1.215	18.5	1.267
14	3.61	0.557	5.28	0.723	6.66	0.824	8.15	0.911	10.0	1.001	11.3	1.054
19	1.86	0.271	2.95	0.470	3.89	0.590	5.16	0.713	6.44	0.809	7.47	0.873

TABLE IX.—ABSORPTION OF GENERAL X-RADIATION IN ALUMINUM

Initial filtration: Tube wall, 1.29 mm. cerium glass and 2.0 mm. aluminum

I_0 = Incident radiation I = Transmitted radiation $100\,I/I_0$ = Percentage transmission

Copper Filter	60 K.V.		70 K.V.		80 K.V.		90 K.V.		100 K.V.		110 K.V.	
	$100\ I/I_0$	Log $100\ I/I_0$	$100\ I/I_0$	Log $100\ I/I_0$	$100\ I/I_0$	Log $100\ I/I_0$	$100\ I/I_0$	Log $100\ I/I_0$	$100\ I/I_0$	Log $100\ I/I_0$	$100\ I/I_0$	Log $100\ I/I_0$
(mm.)												
0	100	2.00	100	2.00	100	2.00	100	2.00	100	2.00	100	2.00
1	67.5	1.829	69.2	1.840	72.0	1.858	72.9	1.863	74.9	1.875	76.0	1.881
2	49.1	1.691	51.8	1.714	55.1	1.741	57.0	1.756	59.6	1.775	61.3	1.787
3	36.8	1.566	40.5	1.608	43.9	1.263	45.9	1.661	49.3	1.693	51.1	1.708
4	24.4	1.454	32.6	1.514	36.0	1.556	38.3	1.584	41.6	1.619	43.8	1.642
5	22.9	1.360	26.6	1.424	30.0	1.477	33.0	1.518	36.0	1.557	38.2	1.582
6	18.7	1.271	22.2	1.345	25.5	1.406	28.5	1.455	31.5	1.499	33.7	1.528
8	12.8	1.103	16.4	1.216	19.1	1.281	21.5	1.333	24.8	1.394	26.7	1.427
13	6.10	0.785	8.60	0.935	10.5	1.020	12.6	1.099	14.9	1.174	16.3	1.213
18	3.15	0.498	4.80	0.681	6.12	0.787	7.96	0.901	9.56	0.981	10.8	1.033

TABLE X.—ABSORPTION OF GENERAL X-RADIATION IN ALUMINUM

Initial filtration: Tube wall, 1.29 mm. cerium glass and 4.0 mm. aluminum

I_0 = Incident radiation I = Transmitted radiation $100\,I/I_0$ = Percentage transmission

Copper Filter	60 K.V.		70 K.V.		80 K.V.		90 K.V.		100 K.V.		110 K.V.	
	$100\ I/I_0$	Log $100\ I/I_0$	$100\ I/I_0$	Log $100\ I/I_0$	$100\ I/I_0$	Log $100\ I/I_0$	$100\ I/I_0$	Log $100\ I/I_0$	$100\ I/I_0$	Log $100\ I/I_0$	$100\ I/I_0$	Log $100\ I/I_0$
(mm.)												
0	100	2.00	100	2.00	100	2.00	100	2.00	100	2.00	100	2.00
1	75.0	1.875	78.3	1.894	79.8	1.902	80.4	1.905	82.6	1.917	83.3	1.921
2	57.9	1.763	63.0	1.799	65 3	1.815	67.2	1.828	69.8	1.839	71.4	1.854
3	46.6	1.668	51.3	1.710	54.4	1.736	57.8	1.762	60.5	1.782	62.2	1.794
4	38.0	1.580	42.8	1.631	46.2	1.665	50.0	1.699	53.0	1.724	55.0	1.741
6	26.1	1.417	31.7	1.501	34.7	1.540	37.7	1.577	40.9	1.612	43.6	1.639
11	12.4	1.094	16.6	1.220	19.0	1.279	22.0	1.342	25.1	1.399	26.6	1.425
16	6.42	0.807	9.28	0.968	11.1	1.046	14.0	1.145	16.5	1.218	17.6	1.245

standard conditions as the facilities permitted.[23]

Since, as pointed out by Lauritsen,[24] the international definition of the roentgen permits disturbing conditions to enter at these high potentials, our measurements were made according to the revised definition of the roentgen recommended by the Radiological Society of North America Standardization Committee.[25] Here all forms of scattered radiation are eliminated as far as possible from the measuring volume of the ionization chamber.

The end of the tube containing the target and its water jacket was surrounded by a lead cap 1 inch thick in which a hole about $^3/_4$ inch in diameter was drilled to serve as a window for passing the radiation. The filters were inserted in the beam immediately adjacent to the lead cap, and the limiting diaphragm for the ionization chamber placed 35 cm. from these. This diaphragm consisted of a 2.5 cm. square hole half way out the radius of a large circular lead disc 2.54 cm. thick. Following the technic described by Lauritsen, the beam was cut off, without altering the amount of extraneous radiation entering the ionization chamber, by rotating this lead disc on its geometrical axis. The difference in reading of the ionization chamber magni-

[23] Only a brief description of these is given here as others will undoubtedly publish a more adequate one.

[24] C. C. Lauritsen. Am. Jour. Roentgenol. and Rad. Ther., 1933, XXX, 380.

[25] "The roentgen is the quantity of x-radiation which when the secondary electrons are fully utilized and the effects of all scattered radiation avoided, produces in one cubic centimeter of atmospheric air at 0° C. and 76 cm. mercury pressure, such a degree of conductivity that one E.S.U. of charge is measured under saturation conditions."

tude with the limiting diaphragm open and closed eliminated the effect of radiation scattered from the room.

The ionization chamber was of the parallel aluminum plate type, having a 28 cm. spacing between the plates. That this separation was probably sufficient, at the voltages used, is concluded from cloud expansion photographs[26] which show that at a considerably higher peak voltage the bulk of the ion tracks are confined within 10 cm. of the sides of the beam.

The ionization current was measured by a high sensitivity galvanometer and voltages—corrected to sea level—by the spark gap between 50-cm. spheres placed in accordance with 1928 A. I. E. E. standards. These potential measurements were in reasonably close agreement with the sum of potentials measured individually on each of the cascaded units by the manufacturer.

The resulting semilogarithmic copper absorption curves, for the indicated excitation potentials and an initial filtration equivalent to about 6 mm. of copper, are plotted in Figure 6. Along with these is also plotted the curve for radiation excited by 180 K.V. (constant) and initially filtered by 4.8 mm. of pyrex glass—equivalent to 0.1 mm. of copper; that obtained by Mayneord[27] for 370 K.V. (constant), but an unstated initial filtration, and, of radiation from a sample of Ra (B + C) after "a heavy" initial filtration (also from Mayneord). The half value

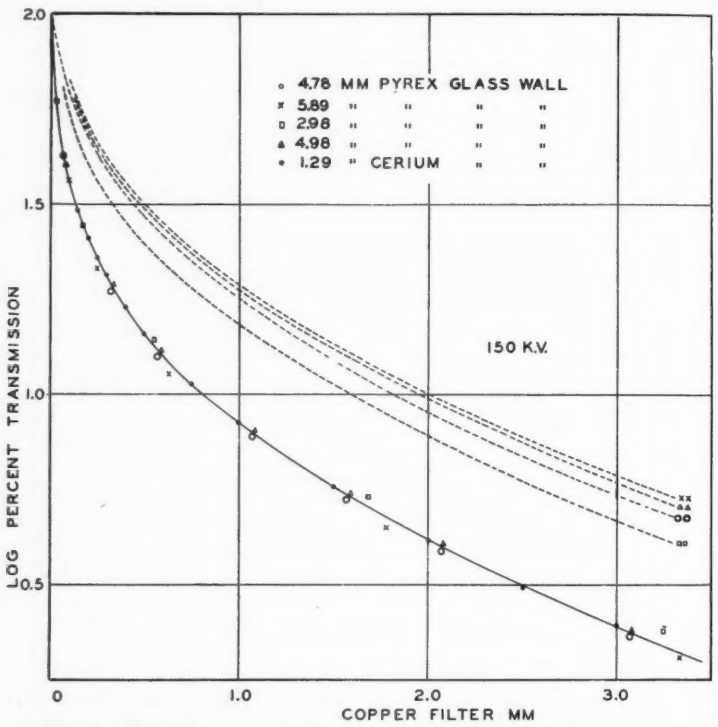

Fig. 5. Absorption curves made with several tubes showing the correction for wall effect.

[26] C. C. Lauritsen. Personal communication.

[27] W. V. Mayneord. Brit. Jour. Radiology, N. S., 1933, VI, 321.

TABLE XI.—COPPER AND ALUMINUM EQUIVALENTS OF PYREX GLASS FOR RADIATIONS EXCITED BY VARIOUS CONSTANT POTENTIALS AND FILTERED BY 1.3 MM. OF CERIUM GLASS (COPPER EQUIVALENCE, ABOUT 0.02 MM.)

Thickness of pyrex	100 K.V.			110 K.V.			120 K.V.			130 K.V		150 K.V.	
	Log p. c. transmission	Cu thickness	Al thickness	Log p. c. transmission	Cu thickness	Al thickness	Log p. c. transmission	Cu thickness	Al thickness	Log p. c. transmission	Cu thickness	Log p. c. transmission	Cu thickness
0 mm.	2.00	0 mm.	0 mm.	2.00	0 mm.	0 mm.	2.00	0 mm.	0 mm.	2.00	0 mm.	2.00	0 mm.
2	1.657	.02	.80	1.667	.025	.95	1.720	.025	1.05	1.756	.023	1.804	.024
4	1.477	.067	2.10	1.508	.064	2.15	1.539	.066	2.22	1.604	.065	1.640	.070
6	1.354	.115	3.52	1.382	.117	3.70	1.405	.125	3.80	1.459	.125	1.512	.124
8	1.265	.157	5.00	1.301	.167	4.70	1.330	.175	5.25	1.362	.180	1.428	.180
10	1.176	.205	5.95	1.225	.22	6.15	1.258	.23	6.6	1.292	.237	1.356	.245
12	1.079	.260	7.25	1.146	.28	7.40	1.182	.30	7.9	1.225	.30	1.288	.32

layer line is also inscribed at $\log_{10} 50 = 1.70$.

Owing to the very different excitation potentials and initial filtrations involved in radiations of Figure 6, as compared with

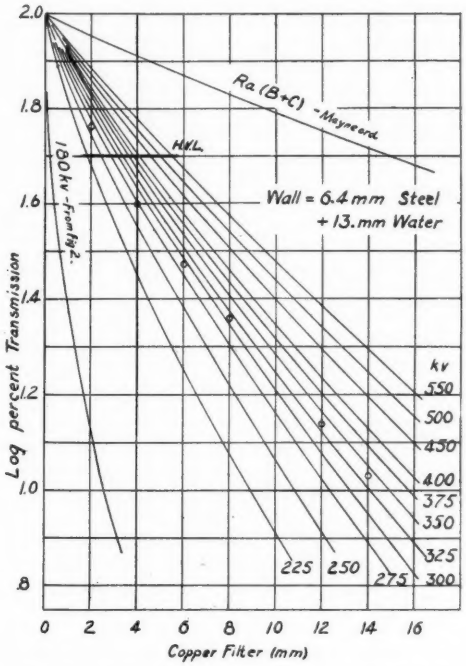

Fig. 6. Copper absorption curves above 225 K.V.; voltages are peak values which are the same as the effective values within the limits of error of measurement.

those of Figures 1 and 2, no attempt is made to correlate the absorption curves of Figure 6 with the basic curves of Figure 1.

For the 370 K.V. (constant) curve of Mayneord the initial filtration was confined to the tube wall and hence was of much smaller copper equivalent than that (about 6 mm.) in our measurements. In this respect Mayneord's curve agrees with our 375 K.V. curve at the lower copper filtrations in that his drops the more rapidly as it should, but at the highest filtrations somewhat greater slope of our curve denies the agreement. Since his measurements were made with a thimble chamber of unknown wall effect, it seems rather

TABLE XII.—ALUMINUM EQUIVALENTS OF LIME GLASS FOR RADIATIONS EXCITED BY VARIOUS CONSTANT POTENTIALS AND FILTERED BY 0.45 MM. OF LIME GLASS

Thickness of lime glass	60 K.V.		80 K.V.		100 K.V.	
	Log p. c. transmission	Al thickness	Log p. c. transmission	Al thickness	Log p. c. transmission	Al thickness
0 mm.	2.00	0 mm.	2.00	0 mm.	2.00	0 mm.
.5	1.607	.42	1.690	.47	1.751	.48
1.0	1.516	.84	1.558	.86	1.605	.88
1.5	1.403	1.26	1.461	1.38	1.526	1.33
2.0	1.295	1.72	1.373	1.76	1.459	1.78
2.5	1.185	2.16	1.286	2.23	1.395	2.24
3.0	1.072	2.56	1.199	2.74	1.322	2.77

gratifying that the results are not even more divergent.

Inasmuch as our curves of Figure 6 were obtained with nearly constant potential—2 per cent ripplage—they may serve as standard for specifying radiation quality within the range of excitation potentials covered and for the initial filtration of about 6 mm. of copper. Absorption curves obtained with a greater initial filtration can be correlated with these curves of Figure 6 just as those of Figure 2 with Figure 1; but not so with curves for radiation of lower initial filtration because of the uncertainty with which the magnitudes can be extrapolated toward the higher transmissions. In other words, although these curves can be of value as standards, they do not have the range of application reserved to basic curves—*i.e.*, of radiation subjected to zero initial filtration.

We would suggest, therefore, that in specifying the radiation in this high potential range the peak of the excitation voltage be stated when possible along with the equivalent constant voltage until further studies have been made.

Recognition is due to Mr. C. F. Stoneburner of this laboratory for his valuable assistance in obtaining much of the data.

RECENT ADVANCES IN ENCEPHALOGRAPHY[1]

By CORNELIUS G. DYKE, M.D., *and* LEO M. DAVIDOFF, M.D., *New York City*

ENCEPHALOGRAPHY, in spite of its relatively recent development, is already one of the important diagnostic procedures used in neurologic and neurosurgical clinics. The method has attained this degree of importance even though up to the present time interpretation of the encephalograms has been based only upon the gross abnormalities seen in the ventricles and the subarachnoid space. Reliance upon this method of diagnosis will undoubtedly continue to increase as the finer cerebral structures are recognized and the significance of abnormal variations in them is appreciated.

The increase in the accuracy of encephalographic diagnosis depends upon a thorough acquaintance with the appearance of the normal cerebral structures. It, therefore, seems advisable to describe the various structures which can be outlined when the cerebrospinal fluid spaces are filled with air.

Two phases of encephalography will be presented here: the technic, and the appearance of the normal subarachnoid space and the structures bordering upon or contained within it.

TECHNIC

The technic of encephalography varies from one clinic to another and each method has its good and its less favorable features. The method employed at the Neurological Institute of New York, the description of which follows, has proved to be simple and safe in over 1,100 cases.

The evening before encephalography is to be performed, the patient is given sodium amytal, grs. 3 (0.2 gram), to insure a restful night. The following morning the dose is repeated an hour prior to the procedure, and about fifteen minutes before the lumbar puncture the patient is given morphine sulphate hypodermically: adult, grs. $^1/_6$ to $^1/_4$ (0.01 to 0.015 gram); children, grs. $^1/_{12}$ to $^1/_8$ (0.005 to 0.007 gram). Breakfast is withheld. Following this, the patient is sent to the roentgen-ray department where the entire procedure is carried out.

During the withdrawal of fluid and the introduction of air, notes are made of the patient's status, blood pressure, pulse, respiration, or any change in condition such as sweating, pallor, headache, or syncope. To combat these symptoms, aromatic spirits of ammonia and caffeine sodium benzoate have proved sufficient and are always kept at hand.

The patient is seated on a small bench with the forehead resting against an upright Potter-Bucky diaphragm. Lumbar puncture is made with the patient in this position under local anesthesia (procaine). Even when a general anesthesia is used, the same position is employed, this position being maintained throughout the procedure. Only one lumbar puncture is made through the third or fourth lumbar interspace. The pressure of the spinal fluid is recorded and 10 c.c. of cerebrospinal fluid are withdrawn and 5 c.c. of air injected. Atmospheric air for injection is sucked into the syringe through several thicknesses of sterile gauze to avoid possible contamination by air-borne bacteria. It is important to withdraw the fluid and inject the air slowly so that the intracranial pressure changes will not be abrupt. The fluid should be allowed to displace the plunger of the syringe without using suction. In the average case one minute is required for the removal of 5 c.c. of fluid. Five c.c. of air are then injected at a rate of speed equal to that for the withdrawal of the fluid. After the initial 10 c.c. of

[1] Read before the American Congress of Radiology, at Chicago, Sept. 25–30, 1933.

Fig. 1. Sagittal hemisection of the brain with the piarachnoid and blood vessels undisturbed. (*A*) anterior cerebral artery; (*B*) anterior communicating artery; (*C*) cisterna chiasmatis; (*D*) optic nerve; (*E*) optic chiasm; (*F*) infundibulum; (*G*) tuber cinereum; (*H*) oculomotor nerve; (*K*) corpora memmillaria; (*L*) posterior cerebral artery; (*M*) cisterna ambiens (central portion); (*N*) cisterna interpeduncularis.

fluid have been withdrawn and 5 c.c. of air injected, 5 c.c. of fluid and 5 c.c. of air are alternately withdrawn and injected until the desired amount of air has been introduced. It is desirable to end the procedure with 5 c.c. less air injected than fluid withdrawn, for it is known that 100 c.c. of air at room temperature (20° C.) when raised to body temperature (37.5° C.) expands to a volume of approximately 103 cubic centimeters. An 18-gauge spinal puncture needle is used and a short piece of rubber tubing, 4 cm. in length, connects the needle and the syringe. This tubing allows considerable manipulation of the syringe without affecting the needle, and may be compressed with the thumb and forefinger instead of using a stop-cock.

There is still considerable debate concerning the optimum amount of fluid to be withdrawn and the quantity of air to be injected. At this clinic, the first film is taken in the postero-anterior position after 25 c.c. of fluid have been removed and 20 c.c. of air injected. While this film is being developed the procedure is continued, and by the time 45 c.c. of fluid have been withdrawn and 40 c.c. of air injected, the wet "20 c.c. film" is ready to be viewed by the roentgenologist and the operator. From this film the position, shape, and size of the lateral and often also of the third ventricles may be determined. Having this information, it is quite easy with a little experience to determine the total amount of air that will be necessary to give a satisfactory encephalogram. The estimation of the amount of air to be injected in any particular patient is based upon the fact that the normal ventricular system has a capacity of from 18 to 20 cubic centimeters. The capacity of the cerebral subarachnoid space has not been determined accurately but it has been found that from 50 to 70 c.c. of air are sufficient to outline the ventricles and subarachnoid space satisfactorily when the ventricles appear normal in the 20 c.c. film. Patients with larger ventricles require correspondingly larger amounts of air. However, 140 c.c. of air have been found sufficient even in cases with marked hydrocephalus. Manipulation of the head during the introduction of the air, in order to obtain satisfactory encephalograms, is not essential.

The position of the patient while the roentgenograms are being made has aroused considerable discussion. Many workers favor the vertical position, and others, equally enthusiastic, prefer the horizontal. At this clinic, anteroposterior, postero-anterior, and right and left lateral stereoscopic films are taken with the patient upright. Immediately following these, a complete stereoscopic set of films from the four sides of the head is made with the patient horizontal. This has proved necessary since certain structures appear more often in the vertical films, whereas other structures are most frequently seen in the films taken with the patient recumbent.

The roentgenologic technic used is as follows: (*A*) Kilovolts, 75 to 80; (*B*) milliamperes, 25 to 30; (*C*) time, 3 to 4 seconds; (*D*) target-to-film distance, 30 inches; (*E*) intensifying screens; (*F*) curved Potter-Bucky diaphragm; (*G*) cloth binder for immobilization; (*H*) filter, 1 mm. aluminum.

It is perfectly safe to take as many as 17 films, routinely. Indeed, the entire series

of exposures has often been repeated within a week and no untoward effects have ever been noted.

The symptoms encountered during and after the procedure may be headache, nausea, vomiting, cyanosis, pallor, perspiration, chilliness, drowsiness, poor pulse, and a fall of the blood pressure. Headache is the first symptom of which the patient usually complains. Ordinarily, this occurs after the injection of 20 c.c. of air but it may be complained of before. One or several of the other symptoms then follow rapidly. The great advantage of using the smaller amounts of air is that frequently, before any or many of the symptoms have appeared, the procedure is completed. In other words, it has been found at the Neurological Institute that *the number and severity of the symptoms both during and following encephalography are directly proportional to the quantity of air that has been injected.*

THE CEREBRAL SUBARACHNOID SPACE: THE BASAL CISTERNS

The arachnoid adheres closely to the pia mater everywhere except over parts of the ventral surfaces of the brain and the sulci. In the former region, the leptomeninges are widely separated from each other and form spaces called "the subarachnoid cisterns" (Fig. 1). The cisterns communicate freely with one another and with the spinal subarachnoid space. They are usually named according to the cerebral structures which bound them: thus, there is a cisterna magna, pontis, interpeduncularis, chiasmatis, laminæ terminalis, corporis callosi, fossæ Sylvii, and ambiens. These cisterns have a fairly constant appearance in the roentgenogram and many of them are visualized in a high percentage of cases. For this reason, their absence or distortion in a roentgenogram is often of diagnostic significance.

Cisterna Magna.—In 1874,[2] this cistern was designated by Key and Retzius as the "Cisterna Magna Cerebello-Medullaris." According to them, the cistern is directly continuous with the subarachnoid space of the spinal canal. On entering the cranial cavity at the foramen magnum, the subarachnoid space expands greatly in all directions to form the cisterna magna. Dorsally, it extends over the medulla oblongata, the tela choroidea of the fourth ventricle, and the cephalic and ventral portion of the vermis of the cerebellum. It includes, moreover, the larger part of the vallecula and continues laterally over the tonsils and a portion of the ventral and caudal aspects of the cerebellar hemispheres. Cephalically, the cistern is continuous with the cisterna pontis, while dorsally it is continuous with the cisterna ambiens.

The appearance of the cistern in the roentgenogram varies considerably in size and shape. It is best visualized in the lateral stereoscopic views and may be easily identified if one follows the air upward along the dorsal aspect of the spinal cord through the foramen magnum. Usually it appears as a single or double sickle-shaped shadow, the inner margin being concave ventrally, the outer margin paralleling the inner surface of the occipital bone. The cistern extends from the foramen magnum to the grooves for the transverse sinuses, being limited cephalically by the tentorium at a point opposite the internal occipital protuberance (Fig. 2). The cerebellar vermis produces the inner concave margin. Here in the mid-line the cistern occupies the vallecula, is deepest, and is the portion most easily seen in lateral encephalograms. The lateral extensions of the cistern are visible only when the films are viewed stereoscopically. The depth of the cistern in the vallecula varies from 5 mm. to 2 cm. in the encephalogram.

Frequently the air in the cisterna magna extends dorsally and cephalically over the dorsal surface of the cerebellum, to become continuous with the air in the cisterna ambiens. When the air penetrates into the cerebellar sulci, it appears irregularly scalloped as it passes between the indi-

[2] Nord. Med. Archiv., 1874.

vidual folia of the cerebellum (Fig. 3), but when it fails to enter these sulci, the air appears evenly distributed over the surface of the cerebellum without any finger-like projections.

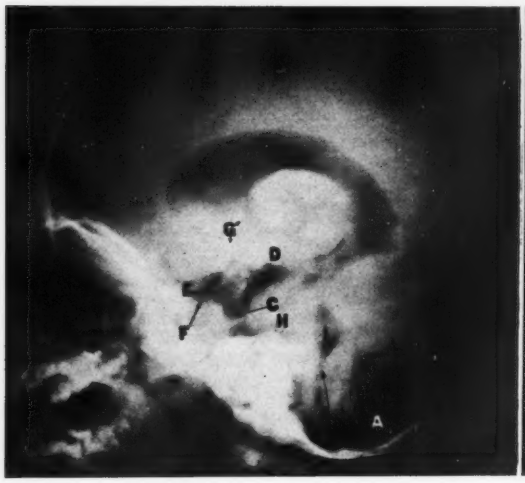

Fig. 2. No. 24,681. Encephalogram showing: (*A*) cisterna magna; (*B*) foramen of Magendie; (*C*) cisterna pontis; (*D*) cerebral peduncles; (*E*) cisterna chiasmatis; (*F*) diaphragm sellæ; (*G*) lamina terminalis; (*H*) pons Varolii; (*I*) fourth ventricle.

Fig. 3. No. 24,777. Lateral encephalogram outlining: (*A*) cerebellar folia; (*B*) posterior cerebral artery; (*C*) infundibulum; (*D*) optic chiasm and nerves; (*E*) anterior communicating artery; (*F*) pineal body; (*G*) suprapineal recess of the third ventricle; (*K*) colliculi; (*L*) third ventricle.

Not infrequently a column of air is seen in the mid-line joining the caudal end of the cisterna magna and the fourth ventricle. In many instances, even after careful stereoscopic study of the films, no break in this streak of air can be detected and the communication between these two cavities, presumably the foramen of Magendie, is therefore demonstrable (Fig. 2).

Cisterna Pontis.—On the ventral aspect of the pons, the cisterna pontis is located. This cistern has free communication caudally with the cisterna magna and cephalically with the cisterna interpeduncularis. The cisterna pontis is divided into three parts, a medial and two lateral. The former presents a tunnel-like space in which the basilar artery runs along the ventral aspect of the pons in the mid-line. The artery floats freely in this space except for a few trabeculæ which are attached to it and act as supports. The lateral divisions are traversed by numerous nerves. The facial and acoustic nerves, which have a rather wide arachnoidal sheath, are situated close to the caudal border of the pons. Medially, the cistern is crossed by the abducens nerves, which in their course cephalically and laterally float freely within the cistern for a considerable distance. In the lateral portion of the cistern lie the trigeminal nerves which are surrounded at their exit by a roomy arachnoidal sheath. The depth of the cisterna pontis medially varies from 4 to 6 millimeters.

This cistern is visible in the encephalogram in about 65 per cent of all cases (Fig. 2), and is best seen in the lateral encephalograms. Its ventral border is delimited by the dorsum sellæ and forms a straight line when seen from the side, while the dorsal boundary is formed by the belly of the pons and is concave ventrally. This cistern measures from 5 to 9 mm. in its anteroposterior diameter. While numerous structures cross the cistern, it has never been possible to identify any of them

except the basilar artery, which may be plainly visible for practically its entire length. The profile shadow of the pons Varolii may be seen between the air in the cisterna pontis ventrally and the fourth ventricle dorsally. It corresponds to the appearance of the pons Varolii in the sagittal hemisection of the brain (Fig. 2).

Cisterna Interpeduncularis.—Just cephalad to the cisterna pontis is the cisterna interpeduncularis. Key and Retzius divide this cistern into a superficial (ventral) and a deep (dorsal) portion. The oculomotor nerves pass through the lateral walls of the superficial portion, and the cephalic limit of the lateral portion of the cistern is arch-shaped for their exit. The deep portion of this cistern spreads out laterally between the crura cerebri as well as cephalically over the optic tracts and chiasm, and includes the intercrural trigone with its various structures, the posterior perforated space, the corpora mammillaria, the tuber cinereum, and the infundibulum. These structures, with the deep layer of the piarachnoid, form the roof of the cistern. The posterior cerebral arteries, the posterior communicating arteries, and many smaller branches entering the neighboring brain substance, also cross the cistern.

The cisterna interpeduncularis is irregularly rectangular in shape in the lateral encephalogram. Its longer borders are formed cephalically by the tuber cinereum and infundibulum, and caudally by the belly of the pons. The short ventral border is formed by the posterior part of the diaphragma sellæ and dorsum sellæ, while the dorsal border is formed by the cerebral peduncles. Encephalographically, it is impossible to recognize a definite boundary between the superficial and deep portions of the cistern when both are filled with air, but the superficial portion is much more frequently filled with air than the cistern as a whole. This cistern was visualized in 92 per cent of encephalograms (Fig. 3).

A number of the structures within or adjoining the cistern may be identified in the

Fig. 4. No. 20,102. Encephalogram presenting the (*A*) corpora mammillaria in profile; (*B*) cisterna ambiens; (*C*) superior medullary velum.

encephalogram. The cerebral peduncles, together with the tegmentum of the brain stem, are often visible and are similar in appearance to that seen in a median hemisection of the brain (Figs. 1 and 2). These structures are made visible by the presence of air in the cisterna interpeduncularis ventrally and the caudal portion of the third ventricle and aqueduct of Sylvius, dorsally.

The corpora mammillaria were visible in 28 per cent of this series of encephalograms. These bodies form a rounded projection into the cephalic margin of the cistern, measure about 5 mm. in diameter, and are continuous with the cerebral mass dorsally (Fig. 4).

The tuber cinereum forms a part of the cephalic boundary of the cistern. It appears as a straight line when seen from the side, and extends from the corpora mammillaria caudally and dorsally to the optic chiasm situated cephalically and ventrally. Whenever the cisterna interpeduncularis is well filled with air, the ventral surface of the tuber cinereum is outlined in the encephalogram (Fig. 2). Furthermore, when the inferior portion of the third ventricle is well filled with air the dorsal margin of the tuber cinereum is visible. Finally, in those cases in which both the cisterna inter-

peduncularis and third ventricle are filled with air, the profile of the tuber cinereum is visible between the two air-filled spaces.

Frequently two shadows of increased density are seen within the cisterna interpeduncularis. One of these, about 2 mm. in width and 1 cm. in length, is linear in shape and runs obliquely across the cistern in a dorso-ventral direction parallel to the tuber cinereum. This shadow corresponds in size, shape, and position to the oculomotor nerves. The other shadow usually appears circular in outline and is about 3 mm. in diameter; occasionally is rod-shaped, and is seen to cross the shadow representing the oculomotor nerves obliquely. It corresponds to the only other structures of demonstrable size within the interpeduncular space, namely, the posterior cerebral arteries (Fig. 3).

Cisterna Chiasmatis.—Extending cephalically from the cisterna interpeduncularis, ventral to the chiasm, and rostrally between the mesial aspects of the diverging optic nerves, there is a superficial shallow cistern, namely, the cisterna chiasmatis.

The cisterna chiasmatis was visible in 78 per cent of the encephalograms made at this clinic (Fig. 3). It is extremely irregular in outline and is usually filled unevenly with air, so that no measurements of it can be made. The cephalic part is shaped somewhat like an inverted comma. The lateral portions of the cistern are visible only occasionally as small irregular globules of air.

The caudal extension of the cistern borders the anterior portion of the diaphragma sellæ. The subarachnoid space on the hypophyseal or ventral surface of the sellar diaphragm is seldom seen, so that the diaphragm is usually outlined by air only on its dorsal surface (Fig. 4).

The infundibulum of the hypophysis is surrounded by the air in the cisterna chiasmatis and forms a short rod-shaped shadow of greater density, running obliquely in a dorso-ventral direction (Fig. 3).

The optic chiasm and nerves are frequently demonstrable in the encephalogram. The chiasm is seen in cross-section as a small ovoid shadow 2 × 3 mm. in size. The optic nerves produce a shadow which is continuous with that of the chiasm—rod-shaped and running obliquely in a dorso-ventral direction, parallel to the shadow representing the oculomotor nerves (Fig. 3).

Cisterna Laminæ Cinereæ Terminalis.—The cisterna laminæ cinereæ terminalis is a median cistern situated dorsal to the cisterna chiasmatis. It spreads out in front of the chiasm upon the free cephalic surfaces of the optic nerves in front of the lamina terminalis, and extends upward along the rostrum of the corpus callosum, filling the spaces between these parts and the ventral surface of the frontal lobes.

In the encephalogram, this cistern when filled with air appears as a narrow streak of decreased density (Fig. 2). It runs in almost a vertical direction and, not infrequently one sees within it a circular shadow of increased density about 5 mm. dorsal and slightly cephalad to the optic chiasm. This shadow is produced by the anterior communicating artery (Fig. 3).

The lamina terminalis forms the caudal boundary of this subarachnoid space and its cephalic surface is outlined in the encephalogram whenever the cistern is filled with air. Moreover, when the ventral and cephalic portions of the third ventricle are also filled with air, the lamina terminalis may be seen in profile as a band-like shadow of increased density (Fig. 2).

Other subarachnoid spaces exist in continuation with the cistern of the lamina terminalis. These accompany the anterior cerebral arteries as they curve around the corpus callosum and are enclosed by the arachnoidal membranes which extend from the ventral margin of the falx to the corpus callosum. Within this membrane is another cistern, the cisterna corporis callosi. In the anteroposterior encephalogram, the air in this cistern is seen to be continuous with that in the callosal sulci laterally.

Cisternæ Fossæ Sylvii.—Between the ventral surface of the frontal lobes and the tips of the temporal lobes there are two

lateral enlargements of the subarachnoid space which communicate freely with the midline cisternæ. Laterally, they are continuous with the subarachnoid space within the Sylvian fissures and are designated as

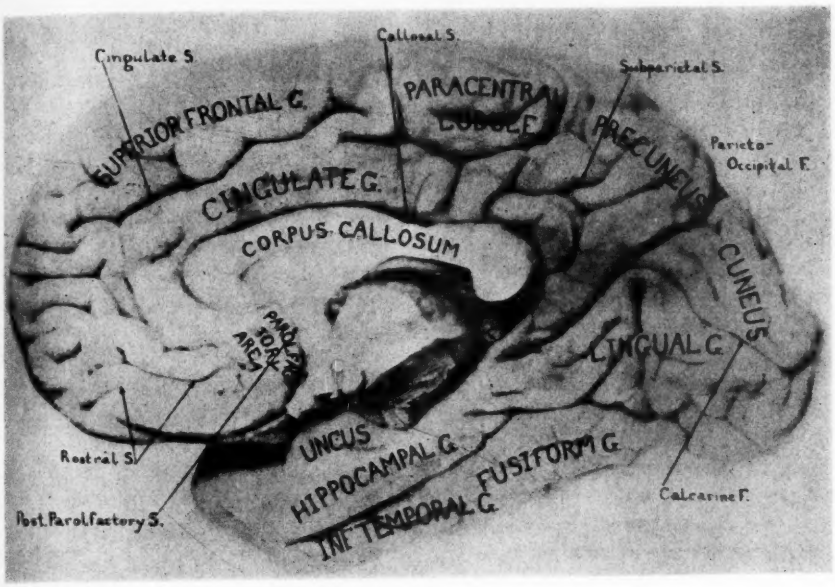

Fig. 5. Mesial aspect of brain reproduced from Retzius' "Das Menschenhirn," Vol. II, Plate LXI. (Labelled by authors.)

spheres and the cerebellum, while its medial walls are limited by the brain stem and the lateral pontine cistern. The cisterna ambiens extends along the floor of the cerebrocerebellar fissure and passes caudally and dorsally on both sides to join its fellow of the opposite side dorsal to the colliculi. Dorsally, it is limited by an arachnoid membrane which stretches between the cerebrum and cerebellum, thus surrounding the mid-brain and, with the ventral cisterns, making a complete cisternal investment about the brain stem.

the cisternæ fossæ Sylvii. Within them are suspended the middle cerebral arteries and their primary branches. The arachnoid stretches across the mouth of the fissure, and the depth of the cistern in its widest portion is from 15 to 17 mm., measuring from the stretched arachnoid to the floor.

In the anteroposterior encephalogram, this cistern is seen slightly caudal to the wings of the sphenoid bone. It may also be seen in the lateral encephalogram.

Cisterna Ambiens.—On each side of the cisterna interpeduncularis, and caudal to the medial portion of the cisternæ fossæ Sylvii, is the wide cisterna ambiens which passes caudad in close relationship to the crura cerebri to encircle the mid-brain. Its lateral limits are formed by the hemi-

According to Key and Retzius, the subarachnoid space between the corpora quadrigemina, the cephalic aspect of the cerebellum, and the splenium of the corpus callosum is also a part of the cisterna ambiens (Fig. 1). The vena magna Galeni leave the brain in this region. More recent authors have named this space the "cisterna venæ magnæ cerebri."

In the lateral encephalogram the cistern consists of two parts, a dorsal one (Fig. 4)

which is single and situated above the colliculi, and a ventral portion (Fig. 4) which is paired and situated between the lateral aspects of the cerebral peduncles and the mesial aspects of the hippocampal gyri. The former is bounded by the splenium of the corpus callosum, suprapineal recess, pineal gland, and the straight sinus in the tentorium cephalically and dorsally, the colliculi and superior medullary velum ventrally, and the vermis of the cerebellum caudally. This portion of the cistern is somewhat rectangular in shape when seen from the side (Fig. 4).

The paired ventral portion of the cistern consists of two slit-like shadows, the superior margin of which is slightly concave upward. This represents that portion of the cistern between the crura cerebri and the hippocampal gyri. The air in this portion of the cistern is directly continuous with that in the hippocampal fissures (Fig. 4).

The pineal gland is frequently outlined in the encephalogram by air in the cisterna ambiens caudally and ventrally, and above by the air in the suprapineal recess (Fig. 3). The corpora quadrigemina are often visible due to the presence of air in the cisterna ambiens above and by air in the aqueduct of Sylvius below (Fig. 3). The superior medullary velum can be seen where it joins the roof of the mid-brain when it is outlined by air in the cistern dorsally and in the fourth ventricle ventrally (Fig. 4).

The other structures suspended within this cistern, such as the great vein of Galen, the posterior cerebral arteries, the superior cerebellar arteries, and the trochlear nerves, have not been individually identified in this location.

THE CEREBRAL CONVOLUTIONS AND SULCI

Up to the present time, with very few exceptions, the cerebral sulci as seen in the encephalogram have been considered collectively, and only insofar as they have shown evidence of widening (cerebral atrophy) or obliteration (adhesive arachnoiditis). However, information of much value may be obtained by careful study of the individual sulci, and the gyri outlined by them, *e.g.*: (*a*) closer acquaintance with the appearance of the cerebrum in the living, presumably normal, individual may be gained; (*b*) anomalies may be more readily recognized; (*c*) cerebral lesions may be more definitely localized. Not infrequently, after the introduction by the lumbar route, air fails to enter the ventricles while the sulci are well outlined. It is, therefore, just as important to be able to draw conclusions from the appearance of the sulci when the ventricles are not visible, as it is to make a diagnosis from the appearance of the ventricles.

In order to demonstrate the individual sulci and to avoid confusion, films have been selected for illustration in which a few sulci alone are well shown. In encephalograms in which all the sulci are filled with air, the identification of individual ones is difficult until considerable familiarity with their usual appearance has been acquired.

We have included in our material the encephalograms of a number of patients with cerebral atrophy. The enlargement of the sulci in these cases permits a greater quantity of air to enter these spaces, thereby demarcating the convolutions and fissures more distinctly than in the normal brain. In this manner the individual sulci may be more readily identified and more satisfactorily reproduced.

Certain sulci are regularly visible in the encephalogram; others can be recognized only occasionally, and still others only rarely. The sulci on the medial aspect of the hemisphere are much more consistently and more satisfactorily shown that those on the convexity of the brain. The sulci that are most often seen and most easily recognized, in the order of the frequency with which they appear, are the cingulate, parieto-occipital, calcarine, callosal, Sylvian, superior temporal, central and lateral occipital. The remaining sulci are less frequently visible except when air fills most of the other sulci, under which cir-

cumstances accurate identification is more difficult. All of the major and most of the secondary convolutions and sulci have been at times seen and recognized in this series of encephalograms.

MEDIAL ASPECT OF THE BRAIN

The Longitudinal Cerebral Fissure.—The great cleft between the hemispheres into which the falx projects is often outlined by air. This appears as a heavy streak bisecting the cerebral contents as seen in the anteroposterior or postero-anterior views. Occasionally this fissure is shifted from its median position, as, for example, by a tumor. In encephalograms in which the ventricles do not contain air this displacement may be of great diagnostic significance.

There are four sulci on the medial surface of the brain which are frequently visible in the encephalogram, the callosal, cingulate, parieto-occipital, and calcarine sulci (Figs. 5 and 6). The rostral, parolfactory, and subparietal sulci are less frequently seen. Secondary sulci are often noted but they are quite variable, and anatomists have apparently left them unnamed.

Corpus Callosum and Callosal Sulci.—The corpus callosum forms the roof of the lateral ventricles, and is separated dorsally from the rest of the brain by the callosal sulci. In the encephalogram, in the anteroposterior view, the callosal sulci are often recognizable as two small narrow horizontal streaks extending laterally from the mid-line for about 5 millimeters. Medially, the air in the two sulci coalesces with the air in the longitudinal fissure along the inferior margin of the falx cerebri and the air in the cisterna corporis callosi. The combined shadow is somewhat triangular in shape, and is separated from the shadows of the lateral ventricles by an area of greater density forming a white band on the film. The latter represents the corpus callosum which may vary in thickness at the mid-line from 0.3 to 1.2 centimeters. In the encephalogram with normal-sized ventricles the corpus callosum can be seen as it dips downward in the mid-line between the wings of the "butterfly" pattern formed by the lateral ventricles. The internal angle of this dip often becomes progressively greater as the size of the lateral ventricles increases.

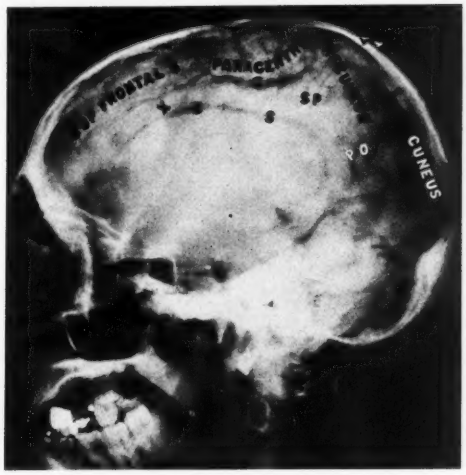

Fig. 6. No. 23,096. Demonstrating many of the sulci and convolutions of the medial aspect of the brain. (*CS*) callosal sulcus; (*C*) cingulate sulcus; (*SP*) subparietal sulcus; (*PO*) parieto-occipital sulcus; (*X*) cingulate gyrus.

Having located the position of the corpus callosum and the callosal sulci in relation to the lateral ventricles as seen in the anteroposterior view, one may now examine the lateral views for the position of these structures. The landmarks for the corpus callosum are formed by the air contained in the ventricles below, and in the unbranched callosal sulci above. Depending upon the amount of air in the callosal sulci, the entire callosum may be outlined (Fig. 6) or only the mid-portion (which is the usual condition), or the posterior portion alone, including the splenium, or the anterior portion alone, including the genu.

Cingulate Gyrus and Sulcus.—Directly dorsal to the corpus callosum on either side of the mid-line are the cingulate gyri (Fig. 6). In the lateral encephalogram, the gyrus is made visible by the air in the callosal fissure below it and in the cingulate

sulcus above it. The cingulate sulcus is readily recognized in the lateral and anteroposterior encephalographic views, appearing in the lateral encephalogram as a broad dark shadow (Fig. 6). The cephalic end of the sulcus begins about 1 cm. anterior to the genu of the corpus callosum and somewhat ventral to it. The sulcus passes upward and forward in front of the curve of the genu of the corpus callosum, at which point it begins to curve backward and upward. In its mid-portion, it is quite smooth for a distance of about 4 cm., where there are, as a rule, two waves or undulations. At the caudal end of the second undulation, the sulcus curves dorsally at a sharp angulation and disappears over the dorsal margin of the hemisphere about 1 cm. caudal to the upper end of the fissure of Rolando (Fig. 6). The short caudal continuation of the cingulate sulcus, parallel to the splenial portion of the callosal sulcus, is usually independent and is called the "subparietal sulcus."

In the anteroposterior view, the cingulate sulci appear as narrow horizontal shadows parallel to and about 1 cm. dorsal to the callosal sulci. The shadows of greater density between the air in the callosal and cingulate sulci represent the cingulate gyri.

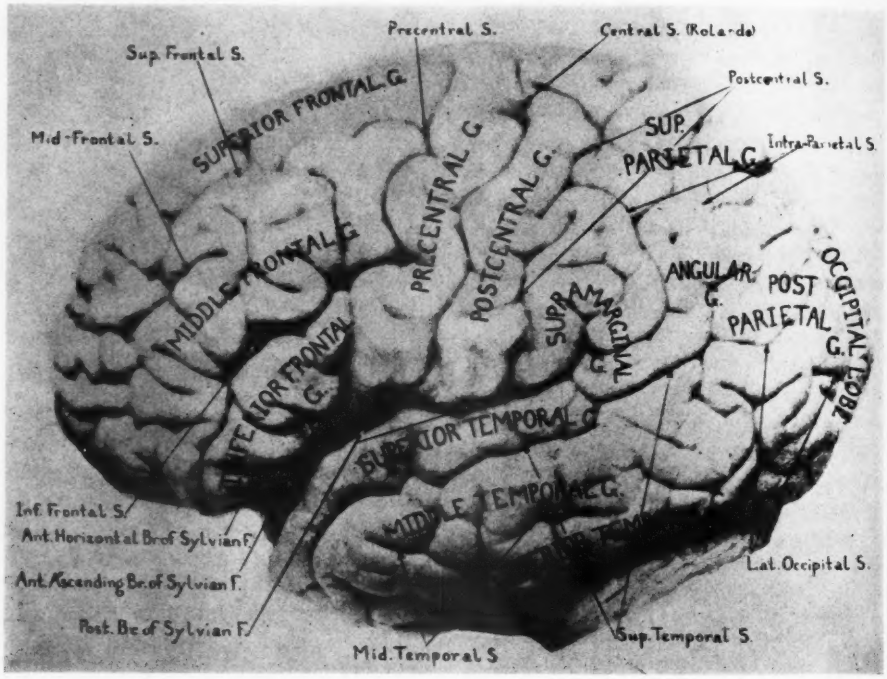

Fig. 7. Lateral aspect of brain reproduced from Retzius' "Das Menschenhirn," Vol. II, Plate LXVII. (Labeled by authors.)

All of these structures are so characteristic in shape and position that they are easily demonstrable in the lateral encephalograms. The only other sulci which may cause confusion are located on the lateral surface of the brain, and the position of the sulci on the convexity can be easily distinguished from those on the mesial surface by examination of the films in the stereoscope.

The Precuneus, Paracentral Lobule, and Superior Frontal Gyrus.—With the major sulci identified in the encephalogram, it

is possible to recognize the important divisions of the brain demarcated by these sulci as seen in lateral roentgenograms (Fig. 6). Between the parieto-occipital fissure caudally and the dorsal sweep of the marginal limb of the cingulate sulcus cephalically is located the precuneus, or the quadrate lobule. Ventrally this subdivision of the mesial surface is demarcated by the subparietal sulcus and dorsally by the dorsal margin of the brain. Through the center of this lobule runs another small fissure which is sometimes filled with air, the superior parietal sulcus.

The part of the brain between the marginal limb and the strongly developed dorsal branch of the cingulate sulcus is the paracentral lobule, limited above by the dorsal margin of the brain, and ventrally by the cingulate sulcus. Cephalad to this lobule may be seen the outline of the mesial portion of the superior frontal gyrus, also called the "marginal gyrus."

Parolfactory Area and Sulci.—The parolfactory area on the mesial surface of the hemisphere is bounded cephalically by a small, inconstant, anterior, parolfactory sulcus and caudally by the posterior parolfactory fissure. The latter is the ventral extension of the cephalic portion of the callosal sulcus and separates the parolfactory area from the subcallosal gyrus. It is not infrequently demonstrable in lateral encephalograms.

Rostral, Orbital, and Olfactory Sulci.—The ventral portion of the mesial frontal (marginal) cortex is indented by two or three sulci which are arranged concentrically with the ventral and cephalic portions of the cingulate sulcus. These are the rostral sulci which divide the ventro-mesial area of the frontal cortex into a number of small gyri. In the encephalogram the rostral sulci are occasionally quite evident and can be seen readily when they become enlarged as a result of cerebral atrophy.

A number of smaller sulci on the orbital surface of the frontal lobe, such as the complex orbital sulci and the olfactory sulcus, are occasionally visible in the encepalogram.

LATERAL ASPECT OF THE BRAIN

The lateral aspect of the cerebral hemisphere presents a much more complex convolutional pattern than that seen on the medial surface (Fig. 7). This is further complicated by the convexity of the lateral surface of the brain. Because of these complicating features, some method for orientation is essential, and the various systems of craniocerebral topography have been investigated with this in mind. The method developed by Taylor and Haughton which utilizes roentgenography, seems to be best suited to the needs of this study. These authors, after formalin fixation of the brain *in situ* for three weeks, made a median sagittal section of the head. The falx cerebri was taken out and the hemisphere removed. Malleable tin wire was then placed in the major sulci and the chief bony landmarks were also marked with similar material. The hemisphere with the wire in the sulci was then replaced in the skull and lateral roentgenograms were taken. These plates showed the relationship between certain fixed points on the exterior of the skull and the sulci as visualized by the wire. In this way they were able to establish lines on any head which correspond quite accurately to the location of the major sulci on the convexity of the brain.

Lateral Cerebral Fissure (*Fissure of Sylvius*).—In the lateral encephalogram the Sylvian "point" from which the three branches of the Sylvian fissure arise, can be seen about 1 to 2 cm. above the tuberculum sellæ. From this point the three branches extend cephalically, dorsally, and caudo-dorsally. The caudal branch has a characteristic termination, which is usually seen in the encephalogram in cases in which the Sylvian fissure is demonstrable (Fig. 8). For more exact identification of the fissure the lines established by Taylor and Haughton may be drawn on the lateral view. The wavy shadow representing the air in the fissure will be found to follow the diagrammatic line representing the same structure. In order to procure the closest

Fig. 8. No. 22,788. This shows especially well the horizontal division of the Sylvian fissure (*PS*). The superior temporal (*ST*) sulcus is seen to parallel the posterior Sylvian branch, and the superior temporal convolution lies between them. From these two sulci the location of the supramarginal (*S*) and angular (*A*) gyri is defined.

Fig. 9. No. 21,296. This is a striking view of the fissure of Rolando (*FR*) and the precentral (*PS*) sulcus locating the central convolution, motor area (*M*) and sensory area (*S*). The view is somewhat distorted due to rotation of the head.

approximation between a particular line in the diagram and the air in the corresponding fissure in the encephalogram, it is essential that the view be a direct lateral one with the two external auditory meatuses practically superimposed.

In the depths of the lateral fissure is located the Island of Reil, a submerged cortical area not visible on the lateral view of the brain unless the overhanging operculum of the frontal and temporal lobes is displaced. The insula is made up of a number of gyri which have a fan-shaped arrangement—the long and short gyri—separated from each other by a series of corresponding sulci. In the anteroposterior encephalogram the surface of the Island of Reil is frequently outlined by a V-shaped collection of air displacing the fluid in the depths of the Sylvian fissure and in the sulci of the insula. The latter may be individually recognized in the lateral encephalogram.

Temporal Lobe and Sulci.—Using the Sylvian fissure as a landmark, it is possible to identify the shadows of the other sulci and convolutions in its vicinity. Paralleling the Sylvian fissure and about 1 cm. ventral to it is the superior temporal sulcus (Fig. 8). This terminates caudally in an upward sweep which is surrounded by the angular gyrus. Between the Sylvian fissure dorsally and the superior temporal sulcus ventrally is situated the superior temporal convolution. About 2 cm. ventral to the superior temporal sulcus is the middle temporal sulcus which roughly parallels the former. Between these two sulci the middle temporal convolution is situated. Both the superior and middle temporal sulci, as well as gyri, are at times demonstrable in the encephalogram. The inferior temporal and collateral sulci, located on the ventral aspect of the temporal lobe, have not as yet been identified encephalographically by the authors. This is probably explained by the inability to obtain encephalographic views with the base of the brain in a favorable position for the visualization of air in these sulci.

The Central Convolutions and Sulci.—The pattern of the central sulcus is quite constant (Fig. 9). In its upper half there is a curve with its concavity cephalically, and in the lower half the direction of this curve is reversed. In the encephalogram, the recognition of the fissure is facilitated by: (*a*) its location in the middle of the hemisphere; (*b*) its relation to the Sylvian fissure, and (*c*) its characteristic course. Further confirmation may be obtained by the use of the Taylor and Haughton lines.

In front of the fissure of Rolando is the precentral or motor convolution (Fig. 9). This gyrus is about 1 cm. in width and is separated from the frontal convolutions proper by the superior and inferior precentral sulci or a combined precentral sulcus (Fig. 9). The latter equals in extent the Rolandic fissure itself and runs parallel to it. If seen alone in the encephalogram it can be distinguished from the central sulcus by its more cephalic position and its proximity to the anterior ascending ramus of the Sylvian fissure which is less than 1 cm. in front of it.

Caudal to the central fissure lies the postcentral gyrus (Fig. 9), which closely resembles the precentral convolution in size, shape, and direction. It is about 1 cm. in width and terminates ventrally near the junction of the middle and caudal thirds of the Sylvian fissure. This gyrus is often interrupted in its mid-portion by a cephalic extension of the intraparietal sulcus. The cephalic boundary of the postcentral convolution is the central fissure. The caudal border of the convolution is less frequently seen inasmuch as the superior and inferior postcentral sulci which delineate it are less often outlined with air (Fig. 9).

The Frontal Convolutions and Sulci.—The convexity of the frontal lobe is divided into three major parallel convolutions, the superior, middle, and inferior, running in the horizontal plane roughly at right-angles to the precentral gyrus.

In the encephalogram, one or several of the frontal sulci are occasionally seen, to be identified in the anteroposterior, postero-anterior, or lateral views. For some unexplained reason the superior frontal sulcus is rarely visible although its depth, uniform position, and direction should facilitate its recognition. The identification of the middle frontal sulcus, although somewhat difficult because its pattern varies considerably, is frequently possible. The anterior horizontal and anterior ascending branches of the Sylvian fissure have a rather constant relationship to the inferior frontal sulcus which makes the latter readily recognizable in the encephalogram.

Posterior Pole of the Cerebral Hemisphere.—The convolutional pattern of this portion of the brain is extremely variable, practically no two specimens being even grossly similar. This makes the identification of structures in this region difficult in the encephalogram, and only two of the sulci, the intraparietal and the lateral occipital, have been observed with reasonable certainty. The former pursues a parasagittal course about 2 cm. lateral to the mid-line. It begins caudally about 3 cm. from the ventral margin of the brain and extends cephalically for about 4 cm. although, because of the convexity of the brain, it is foreshortened in the anteroposterior encephalogram. The lateral occipital sulcus is infrequently seen: when it is visible in the encephalogram, it appears ventral and lateral to the intraparietal sulcus.

SUMMARY

A technic for encephalography which has been found satisfactory in 1,100 cases is described. Emphasis is placed upon the value of taking a trial film after the injection of 20 c.c. of air, and the possibility of obtaining good encephalograms with much less air (50 to 70 c.c.) than has usually been introduced heretofore. In this way, the symptoms of the patients both during and after the procedure are distinctly lessened. The roentgenologic technic is described and the need for stereoscopic films with the patient in the vertical and horizontal positions is shown.

The appearance of the subarachnoid cisterns as seen in the encephalograms is discussed. By an examination of the films in the stereoscope it is possible not only to ascertain the size, shape, and position of all the cisterns, but also their relation to the neighboring cerebral structures. In many instances it has been possible to identify the nerves, blood vessels, and portions of the brain which project into or bound the cisterns.

Furthermore, attention has been directed to the identification of the various cerebral convolutions and sulci on the medial and lateral aspects of the cerebral hemispheres.

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ENLARGEMENT OF THE ATELECTATIC LUNG, A ROENTGENOGRAPHIC SIGN OF INFLAMMATION

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WHEN massive atelectasis[1] has formed in an inflamed part of the lungs or when inflammation has developed in a massively atelectatic part, the inflammatory lesion is wholly or mostly invisible roentgenographically. All shadows of the inflammatory lesion cast by x-ray, except those of any large calcific deposits or air-containing cavities present, blend indistinguishably with the homogeneous shadow of the surrounding airless lung. The lung-field is painted out, so to speak, making calcific bodies and cavities visible, since they are distinctly different in radiolucency from atelectatic tissue. Practical disadvantages arise from this, especially in chronic pulmonary infections wherein the clinical signs of the inflammatory lesion are also masked by the atelectasis. Only the symptoms remain to indicate the nature and extent of the infection, and they are often very inadequate. The disease most prominent in this connection is tuberculosis, with its high incidence and long persistence of both the obstructive and the compressive forms of atelectasis. Bronchiectasis and chronic lung abscess come next in order. The disadvantages are least in acute pulmonary infections in which the symptoms reflect the disease much better and a detailed delineation of the lesion is not so necessary.

The purpose of this paper is to describe a roentgenographic sign indicating the presence and extent of active inflammation in a massively atelectatic part of the lungs, and to present sufficient experimental and clinical evidence to support its validity. The sign rests upon a simple hypothesis concerning pulmonary size, and it requires certain conditions.

Hypothesis.—A massively atelectatic part of the lungs, like any other solid mass of soft tissue, should swell when inflamed and return to its normal size when free again from inflammation, the amount of swelling being roughly proportional to the activity and extent of the inflammation.[2] Therefore, enlargement of a massively atelectatic part should be a sign of inflammation. If the roentgenologist appreciates the size of the x-ray shadow cast by massively atelectatic uninflamed parts of the lungs in general, he should be able to judge in a given case, by the size of an atelectatic part, whether or not inflammation is present and the approximate degree

[1] Basic differences of usage exist as to the meaning of the term "atelectasis" and as to the criteria of the roentgen diagnosis. The authors' usage (1) is, briefly, as follows: Atelectasis is a state of the lungs in which there is complete airlessness and alveolar collapse in all or in any part, however minute. The lesion is *focal* when it occurs in small scattered areas, giving to the lung a mottled appearance at x-ray examination, and *massive* when it occurs in one or more areas, each being large enough to form the homogeneous "ground-glass" roentgenographic shadow which characterizes any gross, completely airless mass of soft tissue of uniform composition. The "ground-glass" shadow is easily recognized, and is the only constant roentgen sign of massive atelectasis. It is usually outlined clearly, so that its shape and distribution permit the lesions of lobar distribution to be distinguished readily from those of sub-lobar or lobular extent. Massive obstructive atelectasis is accompanied characteristically by great displacement of the mediastinum and the *ipso* lateral half of the diaphragm toward the lesion, the displacement being so extensive that it appears at maximum expiration as well as at inspiration. However, when the atelectasis is due to, or at least is associated with, pulmonary relaxation or compression, either or both of these environmental structures is or is not displaced. Any displacement that occurs is irregular in extent and direction.

Both the obstructive and the compressive types of massive atelectasis and only the total uni- or multilobar forms are referred to in this article. Focal atelectasis is not considered.

[2] This is contrary to the behavior of the air-containing lung, for as the products of inflammation collect in the latter they are accommodated by a loss of air, and enlargement is prevented. Indeed, as measured with the lungs at expiration, the pneumonic lung is about normal in size, and at full inspiration, it is much smaller than normal (2 and 3).

of the inflammation. Also, he should be able to determine in a series of observations, by any alteration in the size of an atelectatic part, the occurrence of significant changes in the degree of an infectious process.

Conditions.—(1) The roentgenographic technic should be constant.[3]

(2) In some cases, allowance should be made for shrinkage of the atelectatic part from the contraction of scar tissue. (Although the presence of pulmonary cirrhosis and the amount of shrinkage therefrom in the airless lung cannot always be known, this condition should restrict the value of the sign only to the extent that positive readings—presence of enlargement—would be quantitatively rather than qualitatively inexact, and that negative readings—lack of enlargement—would be inconclusive in completely excluding inflammation.)

(3) The sign should be reliable, only if the possibility of the existence of a neoplasm in the atelectatic part, adding appreciably to the size, is ruled out.

(4) The sign should be regularly usable when the atelectasis involves one entire lobe or group of lobes, since the size and shape of those units are readily carried in mind; but not so, in many cases, when the atelectasis involves only one lobule or a sub-lobar group of lobules, since the proportions of lobules cannot often be remembered.

EXPERIMENTAL SUPPORT

Two groups of dogs were used to demonstrate the relationship, by volume, that exists between the massively atelectatic non-inflamed lung lobe, the massively atelectatic lobe with inflammation of various extents, and the air-containing non-inflamed lobe with various degrees of inflation. In Group 1, two dogs, the right lower lobe was rendered completely atelectatic, and in Group 2, three dogs, the same lobe was first infected and then made atelectatic. The animals were killed, the lungs removed, and the volumes of the right and left lower lobes determined, the left lower lobe being measured both at full inflation and at full collapse. The measurements for the left lower lobe were used to represent the normal size of the right lower lobe.[4]

Group 1. Atelectasis without Inflammation.—Each of the two dogs of this group was given morphine, anesthetized with ether, tracheotomized, and prepared for positive-pressure breathing. The right pleural cavity was opened with an intercostal incision and, as long as the cavity remained open, the breathing was aided with the respirator. The bronchus supplying the right lower and accessory lobes[5] was encircled loosely with a ligature. A long and very slender rubber tube, which was tipped with a short glass cannula, was passed, by way of the tracheotomy opening, into the bronchus. The ligature was then drawn tightly, without knotting, to secure the cannula temporarily. Through the tube, the two lobes thus cannulated were repeatedly ventilated with pure oxygen,[6] and then were inflated completely with the same gas. Immediately after that, the cannula and rubber tube were withdrawn while the ligature was tied permanently onto the bronchus, to retain the gas and obstruct the lobes. Pneumothorax was excluded by expanding the other lobes with air from the respirator, and the lobes were kept expanded while the incision in the chest wall

[3] Our routine thoracic roentgenograms were made with uniform technic. The patient stands upright, hands on hips, shoulders forward, and breast against the cassette changer. Experience shows that small variations in the position of the tube (which is situated centrally, 60 in. from the film), up or down, produce no important changes in the size of the lung-fields at that distance. For example, the two films of a stereoscopic pair commonly present little or no difference in pulmonary size, although taken with a vertical tube-shift of 5.5 inches.

[4] The two lower lobes of the dog's lungs are exactly or very nearly the same volume (2).

[5] The accessory (subcardiac) lobe was included only for the convenience of surgical technic. Because of its unimportance, it is disregarded in the subsequent description.

[6] This served to hasten atelectasis, because of the extremely rapid absorption of oxygen.

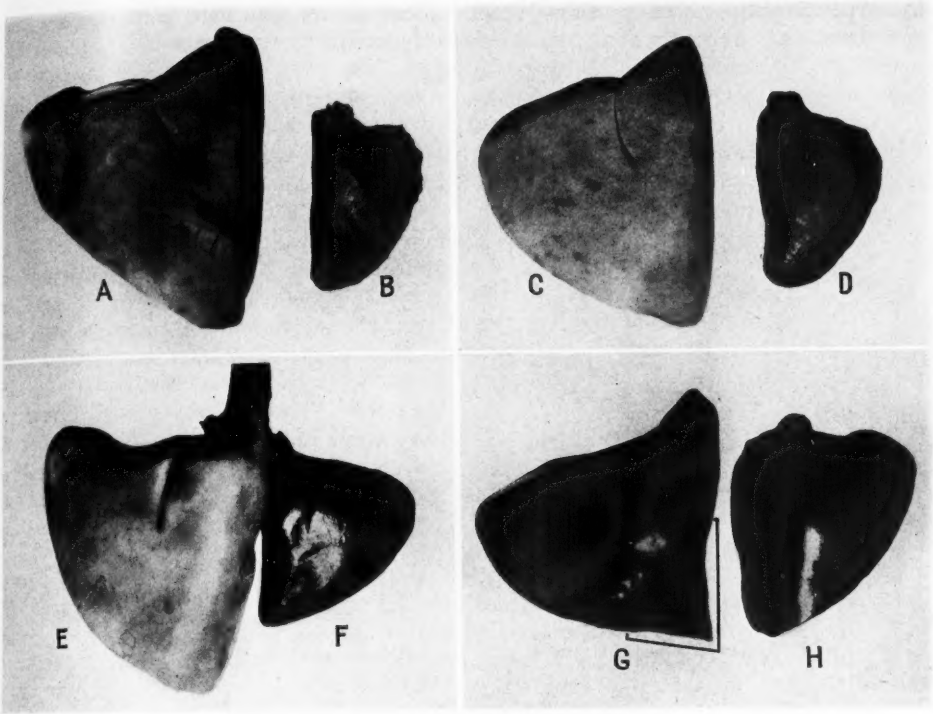

Fig. 1. Four pairs of dogs' lower pulmonary lobes, giving the size relationships. *A*, *C*, *E*, and *G*, normal, fully inflated left lower lobes. (Bracket shows the only inflamed part.) *B*, atelectatic non-inflamed right lower lobe. *D*, *F*, and *H*, atelectatic inflamed right lower lobes, arranged in order of increasing degrees of the inflammation.

was sutured. Two hours later, the dog was killed by exsanguination, the chest was opened, the lungs were allowed to collapse, and the right and left lower lobes were removed and measured, one at a time, in a volumetric chamber (2). The left lower lobe was then inflated with air to the approximate size which it had *in vivo* at full inspiration and was maintained so while its volume was measured again. The lobes were then cut and examined grossly and microscopically.

At autopsy, the right lower lobe of both dogs was found to be liver-color, much shrunken, wrinkled, flabby, and entirely airless (Fig. 1-*B*). The cut surface was the same color, dry, and concave. At microscopic examination, the alveoli were found to be completely collapsed, the capillaries dilated somewhat, and the tissues as a whole free from inflammatory exudate. The left lower lobes presented nothing abnormal (Fig. 1-*A*). The volumes of the right lower lobes were 50 and 61 per cent of those of the corresponding left lower lobes when the latter were collapsed; and 8.5 and 5.9 per cent, respectively, when the left lower lobes were expanded (Table I).

In brief, the result was that the right lower lung lobes were massively atelectatic, free from inflammation, and very small as compared to the corresponding normal left lower lobes, whether the latter were inflated or deflated.

Group 2. Atelectasis with Inflammation of Various Grades.—Each of the three dogs of this group was prepared for thoracotomy as described above, but the operation itself was changed in that the cannula

was ligated permanently into the bronchus, the ventilation with oxygen was omitted, and all of the lobes were inflated with air before closing the incision. Immediately afterward, 3 c.c. of a concentrated culture of pneumococcus (type 1) in saline was injected through the tube into the cannulated lobes,[7] and the tube was left open. Two hours later, the cannulated lobes were ventilated repeatedly with pure oxygen through the same tube, and then the tube was clamped. Two hours later still, the animal was killed and examined in the same manner as were the dogs of the first group.

The right lower lobes of all the dogs were found at autopsy to be dark purple in some regions and liver-color in others, the extent of the purple discoloration being very small in one case (Fig. 1-*D*); somewhat greater in the second (Fig. 1-*F*), and nearly all-inclusive in the third (Fig. 1-*H*). These lobes were distinctly firmer and heavier than the right lower lobes of the dogs of Group 1; the more extensive the purplish discoloration, the heavier was the lobe. The cut surfaces were moist and flat or slightly convex in the regions of purplish discoloration, and were less moist and slightly concave in the other parts. Microscopically, in some sections the alveoli and interstitial tissues were infiltrated with serum and leukocytes and, in others, the airways were free from exudate, and completely collapsed. There was moderate vascular engorgement: all parts were airless. Two of the left lower lobes were normal (Fig. 1-*C* and Fig. 1-*E*), but one (Fig. 1-*G*), the mate of the most inflamed atelectatic lobe, had a small area of light inflammatory reaction along the vertebral margin. The volumes of the right lower lobes were 71, 113, and 198 per cent of those of the corresponding left lower lobes, when the latter were collapsed; and 15.6, 19.1, and 42.8 per cent, respectively, when the left lower lobes were expanded (Table I).

In brief, it was found that the right lower lobes were airless, the seat of both atelectasis and acute inflammation in varying proportions, and much smaller than the corresponding normal inflated left lower lobes, although distinctly larger than the atelectatic non-inflamed lobes in Group 1. The size was proportional to the extent of the inflammation, and was either smaller or larger than the corresponding normal deflated left lower lobes.

TABLE I

Experimental data. Group 1 refers to the dogs with atelectasis and no inflammation, while Group 2 refers to those with both lesions. Dog 1 of Group 2 had the least inflammation and Dog 3, the most.

Group	Dog no.	Volume of right lower lobe (atelectatic) (c.c.)	Volume of left lower lobe		Relation by volume of right lower lobe to left lower lobe	
			(deflated) (c.c.)	(inflated) (c.c)	(l.l. lobe deflated) (%)	(l.l. lobe inflated) (%)
1	1	16	32	191	50	8.5
	2	17	28	286	60.7	5.9
2	1	25	35	160	71.4	15.6
	2	47	41	245	113.2	19.1
	3	107	54	250	198.1	42.8

CLINICAL SUPPORT

The clinical data demonstrate, by roentgenograms, the relationship in size between the massively atelectatic non-inflamed lung, the massively atelectatic lung with inflammation of various extents, and the air-containing non-inflamed lung at inspiration. In all cases the infection was tuberculous, and in some there were certain amounts of secondary non-specific infection. These cases were chosen because they presented little or no distortion of the organ from adhesions,

[7] The intrabronchial injection of virulent pneumococci in dogs produces very regularly a disease closely resembling lobar pneumonia in man (4, 5, 2, 3). The two are similar "in the manner of spread of the lesion; the localization of the process; the immune response; the abrupt termination of the disease by crisis, lysis, or death, and the rapid regression of the process after recovery.... With the evolution of the disease, the lesion passes through the different stages observed in the human pneumonic lung" (4). In the present experiments, it was desired to produce only the early exudative reaction before killing the animal.

and sufficient clinical data for estimating the extent of the pulmonary infection.

Group 1. Atelectasis with Little or No Inflammation.—S. Y. H., male, 40 years of age, 40 days before admission, suddenly developed dyspnea, palpitation, and dizziness of a marked degree during a wrestling bout. The dizziness soon left, but the other symptoms persisted in milder form for 10 days. Without apparent cause, the dyspnea began to grow worse so that, from the fifteenth day on, it almost completely incapacitated the patient. Coughing, which came in occasional light paroxysms, intensified the breathlessness. No degree of fever, sweating, or other signs of toxemia appeared. The only pertinent feature of the past history was that each winter for several years a slight productive cough had occurred. Examination revealed a well nourished, slightly dyspneic person. Typical signs of pneumothorax were found on the left, with extensive displacement of the heart to the right. The pulse was somewhat rapid; the temperature and blood counts were normal. A small amount of mucoid sputum, free from tubercle bacilli, was raised daily. Thoracentesis showed air in the left pleural cavity under tension of from 6 to 10 mm. Hg., and, when 1,500 c.c. of the air was withdrawn, the pressure was reduced to approximately that of the outer atmosphere. A roentgenogram (Fig. 2), made after this treatment, showed the left lung, which was extremely small, to be collapsed and massively atelectatic, with a long slender adhesion extending from the apex to the vertebral end of the second or third rib. The left hemidiaphragm was depressed, and the heart and trachea were displaced slightly to the right. The right lung appeared normal except for an area of increased density opposite the bulge of the heart, due to pulmonary relaxation. The costo-diaphragmatic sulcus on the right was obliterated.

The pneumothorax in this case was apparently the result of a tear in the visceral pleura, probably near the apical adhesion, and the formation of a valvular bronchopleural fistula. The pleural adhesions indicated pre-existing inflammation, possibly tuberculous. The productive cough pointed to an existing bronchitis, evidently non-tuberculous. Judging from the entire lack of symptoms or signs of toxemia at admission, it seemed that the pulmonary parenchyma was free from significant active inflammation. Although the collapsed lung was partly covered by the vertebral column on the x-ray film, the border on that side could be located, from the position of the heart, well enough for estimation of the size. The right and left lungs, as shown by the x-ray film, evidently had about the same relationship in size as the two lobes of the dog (Fig. 1-*A* and Fig. 1-*B*) which were in the same states, respectively, that is, the atelectatic, non-inflamed lung was indeed very small as compared with the fully inflated one.

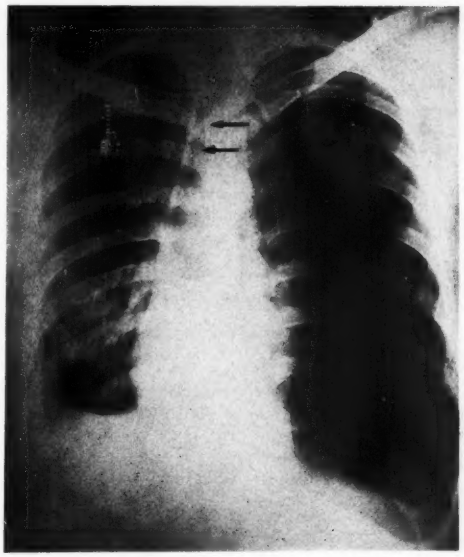

Fig. 2. Case S. Y. H., Group 1. Spontaneous pneumothorax producing atelectasis of the whole non-inflamed left lung. That lung is represented by a small fusiform shadow beside the vertebral column. Arrows, left wall of the displaced trachea.

L. J. C., male, 30 years of age, was admitted to the hospital for sore throat, cough, and fever of two days' duration.

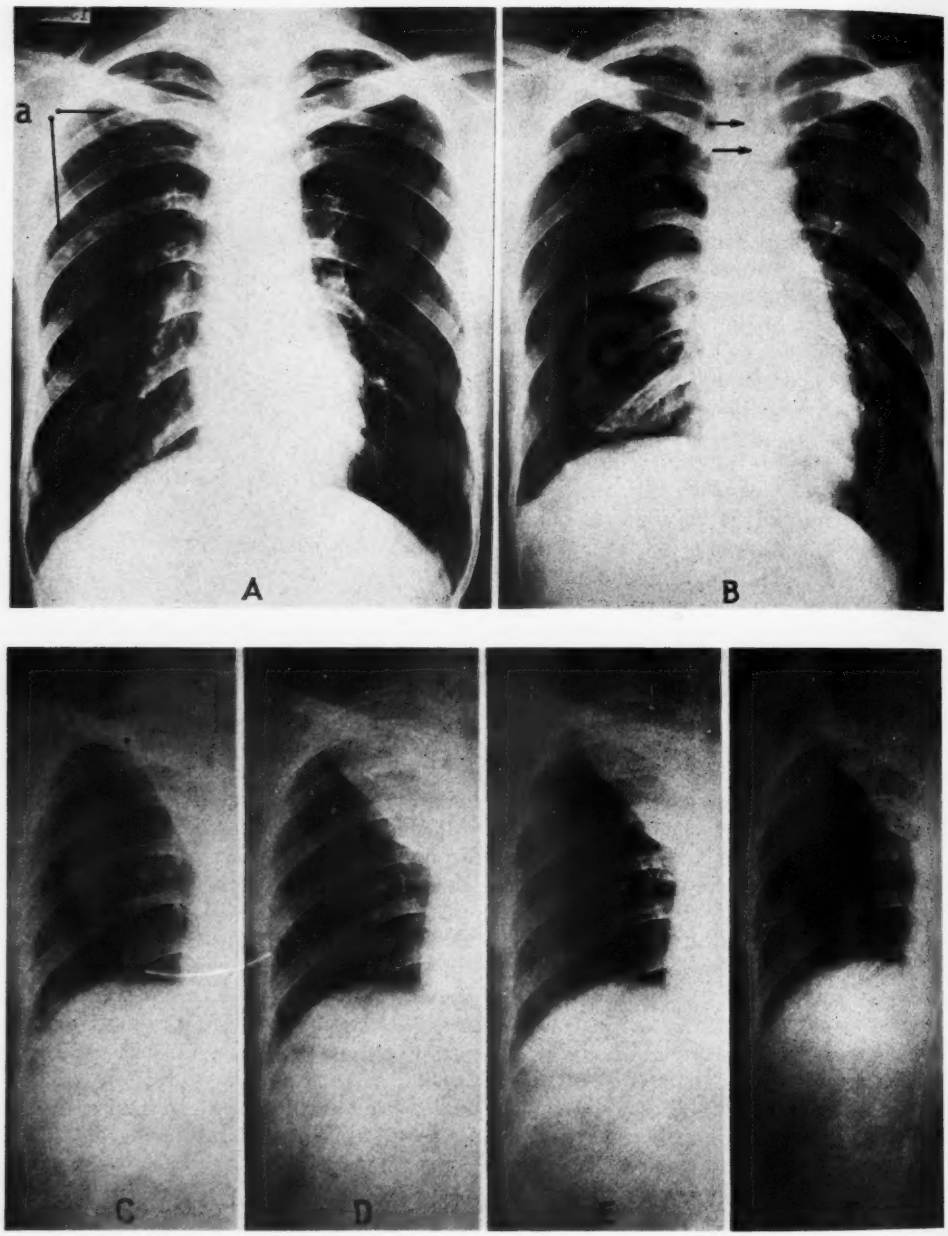

Fig. 3. Case L. J. C., Group 1. Atelectasis of the right upper lobe, at times with active tuberculosis and at other times without it. *A*, before atelectasis (the tuberculosis is at *a*). *B*, during pneumothorax therapy, with atelectasis and slight inflammation of the right upper lobe. The lobe is represented by a moderately large triangular shadow in the upper lung field. Arrows, right wall of the displaced trachea. *C*, *D*, *E*, and *F*, right hemithorax, only, at monthly periods following the abandonment of pneumothorax and the institution of phrenic block. The lobe is shown as a shadow filling the pleural dome, with dots marking, for comparison, one diameter in each view. *C*, period of quiescent infection and a very small lobar diameter. *D*, beginning of new inflammation with a much larger diameter. *E* and *F*, period of subacute inflammation with the diameter slightly smaller and constant.

The past history was unimportant. Physical examination showed only the evidences of a severe upper respiratory infection, but a roentgenogram (Fig. 3-*A*) revealed two areas of light infiltration in the right upper pulmonary lobe, and smears of the sputum were found to contain several tubercle bacilli per microscopic field. After the patient had rested in bed one week, all symptoms except a slight cough had gone. Rest was continued and the tuberculosis was treated with pneumothorax. As a result, the right upper lobe collapsed and became completely atelectatic, while the other lobes were partially collapsed and remained air-containing (Fig. 3-*B*). The atelectatic lobe was suspended by an apical adhesion and appeared moderately large. The right hemidiaphragm was slightly elevated, and the heart and trachea were displaced a little toward the left. Low-grade fever having persistently accompanied the pneumothorax, this treatment was abandoned and phrenicotomy was substituted. As a result the patient showed improvement, consisting of increase in weight, and subsidence of the fever, cough, and sputum. An x-ray examination, five months after the disappearance of symptoms, showed that the right upper lobe, which was very small, was still atelectatic although the pneumothorax was absent (Fig. 3-*C*). The diaphragm on that side was elevated and non-motile.

During the period of the pneumothorax, the size of the lobe and the symptoms were in agreement in indicating slight activity of the tuberculosis. The enlargement of the lobe is quite evident when compared with the size of the lobe's roentgenographic field (Fig. 3-*B*), and the size of the field of the entire atelectatic uninflamed lung of the previous case (Fig. 2). The bronchus of the lobe probably became obstructed during the pneumothorax and remained so, since the amount of air in the pleural cavity was probably insufficient to produce atelectasis from pulmonary compression alone, and

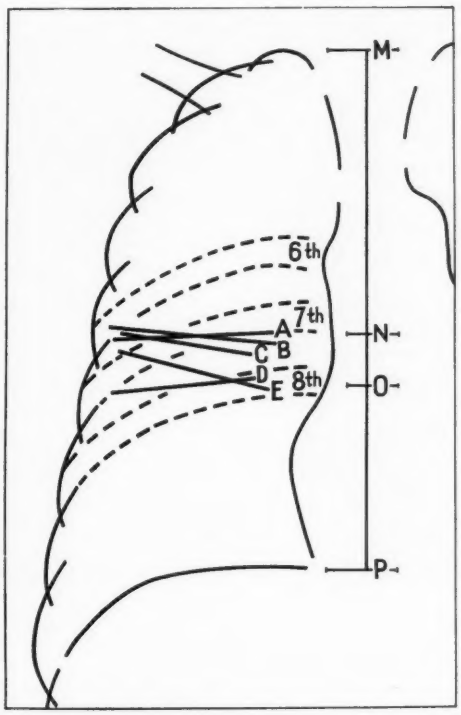

Fig. 4. Diagram of the roentgenographic field of the normal right lung in man. *A*, *B*, *C*, *D*, and *E*, lines indicating the positions commonly taken by the fissure between the upper and middle lobes. *M–P*, height of the entire field. *M–O* and *M–N*, maximum and minimum heights, respectively, of the upper lobe.

since the lobe failed to re-expand after the abandonment of pneumothorax. The obstruction was probably from cicatrix, this being the commonest form of chronic obstruction in pulmonary tuberculosis. Later, when it was clinically evident that the tuberculosis was entirely quiescent, the size of the lobe was in agreement again. The very small size of this atelectatic, apparently non-inflamed, right upper lobe compared with the normal, fully expanded, right upper lobe is seen by comparing the roentgenographic image of the lobe in Figure 3-*C* with the outlines of the lobe in the diagram in Figure 4.

The diagram was made compositely from the thoracic roentgenograms of five persons whose lungs were normal and exhibited the fissure between the upper and

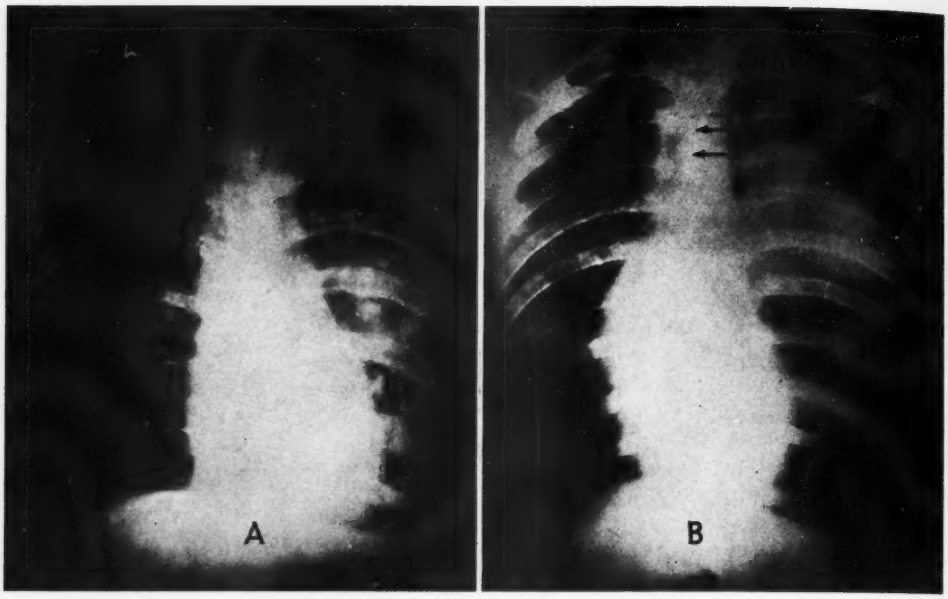

Fig. 5. Case S. Y. D. Atelectasis of an extensively tuberculous left lung. *A*, before atelectasis. *B*, during pneumothorax therapy, with atelectasis. The lung is represented by a very large pear-shaped shadow. Arrows, left wall of the displaced trachea.

middle lobes. The outlines of the right lung-field, and of the posterior portions of the sixth, seventh, and eighth ribs were traced from one film, and then the locations of the interlobar fissure were added by tracing onto the diagram the lines (Figs. 4-*A*, 4-*B*, 4-*C*, 4-*D*, and 4-*E*) of the fissures in the five films. The height of the lung, *i.e.*, the distance from the diaphragmatic plateau to the pulmonary apex (*P–M*), was marked out and the levels of the centers of the uppermost and lowermost interlobar fissures (*N* and *O*, respectively) were indicated on the line.

Measurements from the diagram show that the right upper lobes of these five normal cases were from 55 to 65 per cent by height, and from 46 to 56 per cent by area, of the entire right lung. (The proportion as to height in most cases has been found to hold for the left side also, while the proportion as to area on that side is represented by a larger percentage, because of the cardiac shadow.) Now the area of the roentgenographic image of the right upper lobe in the case that was just described, before atelectasis developed, can be calculated approximately by measuring the area of the entire right lung-field in Figure 3-*A*, and dividing it by one-half (51 per cent being the average of 46 and 56 per cent). The area of the atelectatic, non-inflamed lobe in Figure 3-*C*, when measured for comparison, is found to be one-third. That is, the atelectatic lobe was reduced to one-third the area it had attained when inflated.

Group 2. Atelectasis with Extensive Inflammation of Various Degrees.—L. J. C., the patient just referred to, developed, 18 months after the original onset of the illness, an acute upper respiratory infection with cough, high fever, and, for the first time, leukocytosis (11,000 cells per c.c.) several weeks after having been allowed out of bed. He was returned to bed at once. Roentgenographic examination showed that the atelectatic lobe was

greatly enlarged (Fig. 3-*D*). The upper respiratory infection soon completely subsided, but the cough and leukocytosis persisted, and for periods of from one to two weeks on three occasions during the next four months the patient suffered chills, sweating, high fever, increased cough, and elevated leukocyte count (15,000 to 21,000 cells per c.c.). There was no return of the upper respiratory infection. The sputum was always scanty, mucoid, without offensive odor, and without tubercle bacilli. At each recrudescence, a systematic examination revealed no other cause of the symptoms than the disease of the right upper lobe. Repeated x-ray examinations showed that the lobe remained enlarged, although there persisted a slight reduction in size which appeared two months after the beginning of the episode (Fig. 3-*E* and Fig. 3-*F*).

It seems certain that the toxemia during this episode, just as during the other period, was due to inflammation of the atelectatic lobe, but the chills and leukocytosis suggested a suppurative, non-tuberculous type of inflammation. (The organisms probably entered the lobe, at the beginning of the episode, from the inflamed upper respiratory tract.[8]) The bronchial obstruction prevented drainage, with the result that the sputum carried no telltale products of the inflammation and the infection failed to heal. The acute inflammation apparently was the cause of the remarkable enlargement of the lobe, and the lapse into chronicity that followed was probably responsible for the slight reduction in size during the last two months.

S. Y. D., male, 32 years of age, complained of illness of eight months' duration with productive cough, hemoptysis, fever, sweating, and great loss of weight. Examination showed a poorly nourished and slightly dyspneic person, with signs of exudative tuberculosis over the whole left lung. The pulmonary findings were corroborated by means of the x-ray (Fig. 5-*A*). The sputum was abundant, unoffensive, and rich in tubercle bacilli. There was moderate anemia but no leukocytosis. The temperature fluctuated daily between 37.5° and 39° C. Pneumothorax was instituted and, following three small injections of air, massive atelectasis of the entire left lung appeared (Fig. 5-*B*). The organ was very large and hung from a broad adhesion at the apex. The heart and trachea were displaced slightly toward the right, and the hemidiaphragm was moderately depressed. The large size of the atelectatic lung seemed to reflect the clinical and roentgenographic impressions, before the atelectasis developed, that the lung was extensively inflamed. The organ must have held a great quantity of exudate. The large size is especially evident when compared with the atelectatic lung in Figure 5-*B*, and the atelectatic non-inflamed lung in Figure 2.

C. S. T., female, 32 years of age, was first seen after having been ill for two years with productive cough, hemoptysis, night sweats, marked fever, and progressive loss of weight. The upper half of the right side of the chest was contracted, flat to percussion, and with distant breath sounds, while the lower half exhibited resonance and many râles. The left side presented no abnormal signs. X-rays (Fig. 6) showed the right upper lobe to be massively atelectatic and to occupy almost one-half of the right lung-field. The lobes below were heavily infiltrated with tubercles but otherwise were air-containing, and the lower part of the left lung showed widespread, very light tuberculous infiltration. The trachea and heart were deviated a little to the right, and the right hemidiaphragm was elevated. All evidences suggested a very active and widespread exudative tuberculosis.

Here again, the great size of the atelectatic lobe appeared to reflect the impression, gained from the other roentgeno-

[8] This is quite possible in spite of the obstruction of the bronchus of the lobe, since the bacteria might well have reached the lobe from above either by way of the peribronchial lymphatics, which is believed to be the regular portal in lobar pneumonia (6), or by the blood stream.

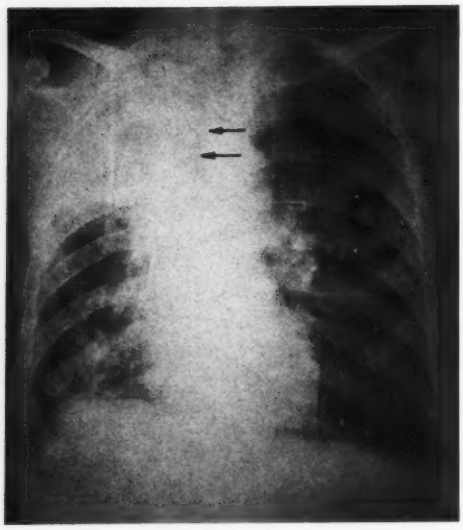

Fig. 6. Case C. S. T. Atelectasis of the right upper lobe and tuberculosis of both lungs. The atelectatic lobe is shown by a large shadow filling the right upper field. Arrows, left wall of the displaced trachea.

graphic and clinical signs, that the lungs were involved by an extensive exudative inflammation. The enlargement is particularly striking when the roentgenographic field of the lobe in Figure 6 is compared with that of the atelectatic non-inflamed lobe in Figure 3-*C*.

CONCLUSIONS

(1) An atelectatic non-inflamed lung is very small in comparison with the fully inflated normal lung (in the dog about one-twelfth, by volume, and in man one-third or less, by area of the roentgenographic image), and also in comparison with the deflated uninflamed lung (in the dog about one-half by volume).

(2) An acutely inflamed atelectatic lung may be considerably larger (in the dog as large as two-fifths, by volume, and in man as large as four-fifths, by area of the roentgenographic image, of the fully inflated uninflamed lung; and in the dog as large as seven times by volume, and in man as large as three times by area of the atelectatic uninflamed lung).

(3) The increase in size of the inflamed atelectatic lung is roughly proportional to the degree of the inflammation.

(4) Enlargement of the atelectatic lung, as estimated from the clinical roentgenogram, can be used under certain circumstances as a sign of inflammation in the lobe.

(5) All of this applies to massive atelectasis only, either obstructive or compressive, and to any one division of the lung. However, the clinical application of the sign is practicable only with atelectasis involving one or more whole lobes, and not smaller divisions.

SUMMARY

Experimental and clinical data are presented to show that, with certain reservations, enlargement of a massively atelectatic lobe of the lungs is a sign of the presence of active inflammation, and that the degree of the enlargement indicates the extent of the inflammation. This sign is adaptable to roentgenographic usage in clinical work and is helpful, particularly when other evidences of existing inflammation are indefinite or lacking.

The experimental data are from dogs, and include accurate volumetric measurements of individual lobes. The data from man give approximate comparative measurements of individual lungs or lobes in terms of the size (area or diameter) of the roentgenographic image. Both the experimental and the clinical data include lungs which are normal, atelectatic and non-inflamed, and atelectatic, while being the seat of inflammation of various extents.

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THE ADVISABILITY OF IMMEDIATE COLONIC IRRIGATION FOLLOWING A BARIUM ENEMA

ESTIMATION OF SOME OF THE DANGERS ACCOMPANYING THE USE OF BARIUM

By MEYER GOLOB, M.D., *New York City*

THE discovery of the utility of opaque substances as a means of visualizing the alimentary tract roentgenographically has been a cardinal factor in the new impetus in gastro-enterology, which has been evident during the last couple of decades. Nevertheless, its development, routine as its use has now become, has not been unattended by occasional upsetting difficulties, unexpectedly covering the attending physician with confusion. Of far more serious significance, they have threatened the well-being of the patient, at times to the point of terminating life.

As with most other important discoveries in medical science, the refinement of the use of roentgenography in gastro-intestinal diagnosis has revolved around three problems: (1) the endeavor to find a non-toxic or least toxic opaque medium; (2) the clinical mapping out of contra-indications, and (3) the recognition of possible mishaps, their prophylaxis, and treatment.

Toxicity of the Medium.—Bismuth, first used as the opaque medium, in spite of its toxicity, was superseded by non-toxic barium sulphate. It was then found through clinical mishap and bitter experience that the substitution in itself was insufficient as a safeguard. It was essential that the insoluble barium sulphate used must be free from contamination with soluble and poisonous barium salts. The poisons of this nature most frequently encountered in clinical practice have been barium chloride, barium carbonate, barium sulphid, barium nitrate, and barium acetate.

Though accidents with barium salts have been comparatively rare, the number of barium meals and enemas given in roentgen-ray work necessitates that the physician shall attend to the purity of the suspension he utilizes. McNally (1), who reviewed this subject in 1925, cited 44 deaths caused by soluble barium salts poisoning, and reported two additional cases. In one of these latter, the physician had erroneously written "barium carbonate" instead of "barium sulphate" in his prescription. The error was not detected by the pharmacist, and the patient died. In the other case, a woman drank barium sulphid in buttermilk, with fatal result. McNally comments on the fact that the barium sulphate given to patients for roentgen-ray examination should be of a chemically pure grade only, should be administered only by the physician who is to make the examination, and that "each lot of barium sulphate should be tested for soluble barium compounds."

On the score of the confusion of the soluble barium salts with insoluble barium sulphate, the U. S. Pharmacopeia cautions: "In prescribing barium sulphate the title should never be abbreviated, to avoid confusion with the poisonous barium sulphide or sulphite." It is axiomatic, too, that as imperative a precaution is necessary with regard to the use of a barium sulphate known to be free of these soluble salts.

Ulcer Perforation Following Diagnostic Barium.—This is a catastrophe which has occasionally been reported in the medical literature. It has seemed to the physicians reporting the cases that the perforation was due directly to the ingestion of the barium. In Cabot's (2) case No. 15,302, the patient, with acute diverticulitis, suffered a perforation 36 hours after a barium enema. Dr. E. P. Richardson, commenting on this sequence, suggests that it would be well to be conservative in regard to the use of barium enemas when diverticulitis is suspected, and it was further suggested that it would be much safer in these cases

to allow a lapse of two weeks or more after an acute attack before attempting diagnosis with barium.

Klein (3), in 1923, Pizzoglio (4), in 1927, and Ein Waldt (5), in 1928, reported similar perforations of duodenal, pyloric, and gastric ulcers apparently due to the diagnostic use of barium or bismuth. Eckman (6), who, in 1928, reported five cases of acute ulcer perforation following barium meals, observed at the Duluth Clinic, where approximately 1,500 gastro-intestinal examinations are done yearly, recommends that patients with ulcer, in whom symptoms point toward a penetrating type of lesion, should be urged to remain within convenient distance of adequate medical aid or should be hospitalized until the danger of perforation after the barium is passed. He considers the following symptoms as contra-indications to all or part of gastro-intestinal examinations: bleeding; unusual and increasing severity of distress; epigastric tenderness and rigidity; failure of food to relieve as promptly and completely as previously; night pain in patients previously free of it, and excessive spasm.

Obstruction of the Colon as a Contra-indication.—Williams (7) has recently suggested that, if obstruction of the colon is acute, great care should be observed in making the x-ray examination and that, even with the barium enema, there is some danger in spite of every precaution; the barium meal is, of course, contra-indicated.

Untoward Reactions from Barium in Malted Milk in Cachectic Patients.—Severe gastric distress and grave hematemesis, following barium administered in malted milk, in a cancer patient exhibiting extreme cachexia and achlorhydria was reported by Summersgill (8), in 1924. Levey (8), in a communication to the same publication, corroborated this apparent sequence from his personal observation in several instances. "Since then," he says, "I have not attempted the use of malted milk in these cases which exhibit emaciation, cachexia, and achlorhydria. . . . It is evident that there occurs, in the process of digestion, fermentation which is of such a type that it cannot be properly controlled by the abnormal gastric and intestinal secretions." He had no difficulty in these cases when he used buttermilk or mucilage of acacia as a base.

Fig. 1. Case 3, showing partial obstruction due to hardened feces after a diagnostic barium enema. This roentgenograph, dated Oct. 29, 1932, shows the colonic tract after evacuation.

UNDUE RETENTION AND HARDENING OF DIAGNOSTIC BARIUM

It has been stated by some authorities that normally the opaque meal should pass from the colon in approximately 24 hours. In my experience, however, a more correct statement would be that it takes 48 hours for the barium meal to be evacuated normally.

Out of a goodly number of barium administrations, I have encountered in my practice three embarrassing cases of undue retention and hardening of a portion of a barium enema. Since it is a mishap which may be frankly injurious and threatening to the patient, its incidence should be recognized and measures taken for its prevention. In the least detrimental of my three cases (Case 1), the x-ray film taken after evacuation of the enema

Fig. 2. Same case, showing bariumized obstructive mass in its colonic location *thirty-six days* following the barium suspension study.

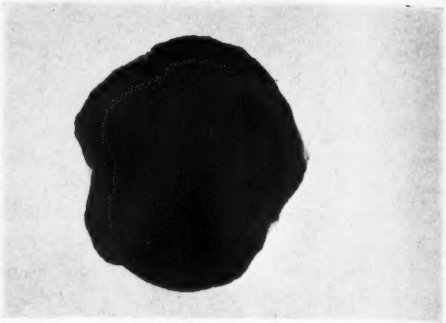

Fig. 3. The bariumized mass after its extraction.

showed retention of the opaque medium in the entire proximal colon. Sixteen days later, there was a sudden onset of abdominal colic accompanied by obstinate constipation. Fluoroscopy disclosed a shadow at the pelvirectal junction, evidently caused by hardened bariumized feces. I was able to dislodge the mass by colonic irrigation, and the symptoms subsided without recurrence.

In the second case (Case 2), the barium mixture was visualized in the iliac portion, and was segmented and apparently embedded in the mucosa. The symptom which led to the discovery of the retention was frank bleeding accompanying the bowel movements. The retention of the opaque medium lingered for about three weeks. Final migration, with expulsion of the stony bariumized feces, was accomplished by administration of oil orally and of retention enemas.

The third case (Case 3) presented the most serious aspect because of the symptomatic simulation of a malignant syndrome. The patient, a female aged 59 years, suffered from achylia, in 1927, as was demonstrated by repeated gastric analysis. She did well, however, on HCl therapy. In 1931, she returned to me for a periodic health examination, at which time, the histamine test revealed a true achylia. Because of the onset of constipation, a barium suspension enema was administered diagnostically. Figures 1 and 2 show the colonic tract before and after evacuation of the enema. Thirty-six days following this suspension study, the patient presented characteristic symptoms of a malignancy, *i.e.*, rapid loss of weight, anorexia, asthenia, and a sense of incomplete evacuation on defecation. However, roentgenologically the findings were negative so far as malignancy was concerned. A proctoscopic examination disclosed a clay-colored mass in the distal colon which I could just reach by digital examination, and which presented a stony hardness to the palpating finger.

Recalling my other two cases of long retention of a barium enema, I prescribed colonic irrigation. Seven gallons of water were used and a large amount of mucus and fecal débris recovered. Believing that the bariumized mass had probably been washed away, I prescribed oil enemas to allay the irritation. The patient returned, however, in three days without relief of symptoms. Protoscopic examination again revealed the mass, which I was finally able to dislodge only through bimanual manipulation intrarectally and intravaginally. Figure 2 shows the mass in its location; Figure 3, the mass as dislodged: its size corresponds in both of these figures.

DISCUSSION

The last case is of special interest because it illustrates the clinical similarity between a simple mechanical obstruction and malignancy. The family physician—quite logically, because of the age and the

symptoms of the patient—had suspected malignancy and was considering the advisability of operation. Fecal impaction, especially at the pelvirectal juncture in a patient beyond the fifth decade, is always suggestive of malignant growth in the distal colon.

To prevent an experience such as I have described, I now order a saline enema immediately after a barium enema, also oil orally for several days, to insure complete evacuation of the barium suspension. I advocate this procedure as a routine measure following roentgenologic study by means of the barium enema.

A cursory review of the literature reveals that there have been several reported cases similar to my own. In 1923, Klein (3) reported an ileus due to impacted barium sulphate, which developed immediately following roentgenography and was fatal in six days. At necropsy, the stony concretions were found to measure 2.2 × 1.4 × 1.2 cm., and had lodged in the sigmoid flexure. He cited two other instances of calculus formation. In Schwarz's case, the barium sulphate concretion was pushed along and voided spontaneously by giving more of the suspension. In Kummat's case, bismuth was used and had piled up as a hard mass in the stomach, raising the question of the safety of administering contrast suspensions in the presence of pyloric stenosis. Orgel (9) reported a case, in 1929, of a partially retained barium meal simulating intestinal obstruction. High rectal washings of oil, water, and peroxide were administered. Oral administration of large amounts of mineral oil and gentle kneading finally cleared the colon of the bariumized material. Orgel emphasizes the fact that, in individuals with atonic bowels, care must be taken as to the amount of barium given and also as to observation of the facility of its passage through the colon. Also, in 1929, Révész (10) reported the retention of barium in the intestine for 43 days.

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CONCLUSIONS

1. The mishaps sometimes, though not frequently, encountered in the use of barium sulphate in gastro-intestinal diagnosis include accidental poisoning due to impurity of the drug, ulcer perforation due to the drug, and undue retention and hardening of the opaque medium causing symptoms or obstruction.

2. Three cases of the latter are presented, and the literature reviewed briefly.

3. The author advocates the routine administration of a saline enema immediately after a barium enema, also oil orally for several days, to insure complete evacuation of the barium suspension.

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A METHOD TO RENDER RADIORESISTANT TUMORS RADIOSENSITIVE[1]

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TUMORS which react favorably to radiation are termed radiosensitive; on the other hand, malignant growths which seem stubborn to radiant energy are looked upon as radioresistant. There are, however, so many exceptions and irregularities to these two classifications that definite grouping is quite out of the question. The fact that a tumor which reacts poorly to x-ray and responds favorably to the gamma rays of radium, and *vice versa*, opens a wide field for discussion. So, too, there are instances in which a tumor does not react well with one particular technic, but behaves like a radiosensitive tumor when another technic is substituted.

These peculiarities raise the question, whether a proper appraisal of the type of tumor and the type of radiant energy employed may not play an important part in changing the character of a so-called resistant neoplasm to one which becomes subsequently sensitive to radiation.

If the degree of malignancy of a given tumor and the degree of radiosensitivity were definitely established, then it would be an easy matter to correlate one with the other. Although we have not up to the present time reached this ideal, there have been, nevertheless, many facts established which have not only advanced our knowledge of radiant energy, but also of the pathologic changes occurring in the tumor.

Radiosensitivity, even of the most sensitive type of tissue, does not mean a constant or a fixed condition. It is very well understood that graded doses of radiant energy are followed by different reactions in radiated tumors. A small dose of radiation stimulates the function the of cell; a larger dose suspends or retards the activity of the cell, while an intense dose destroys the cell by a caustic-like action. It is the quality and quantity of the intensity of the radiant energy which determine the reaction in the cell, although the changes taking place within the cells are by no means alike, since they vary even in cells of the same type.

To appreciate the radio-biologic events which take place in a cell or a tissue, it is necessary to bear in mind that the effect of radiation in a tissue is the result of a primary and a secondary reaction. The primary, or temporary, effect may be so slight as to be followed by complete recovery of the cells; the secondary, or latent, reaction, especially if the dose is intense, may injure the tissue so severely that the destruction produced will have gone beyond the stage of repair. The reaction which follows a definite dose of radiant energy can very well be compared to the effect produced by drugs when used in small, moderate, or large doses.

To emphasize this again, the reaction which takes place in the radiated tumor depends upon: (1) the type of radiant energy employed; (2) the physiologic and biologic state of the cancer cell, and (3) upon the maintenance of the healthy and surrounding tissue. In other words, the effect of a sublethal dose of radiation is quite different from the destructive result which follows an intense dose of gamma radiation. Therefore, the radiant energy should be so employed that the amount administered bears a definite relation to the biologic effect desired, since variation in dosage results in different reactions.

From these facts, it becomes apparent that the therapeutic dose of radiation does not aim only to destroy the tissue; its chief purpose is to prevent further multiplication of the cancer cell and at the same time to stimulate the defensive

[1] Read before the American Congress of Radiology at Chicago, Sept. 25–30, 1933.

mechanism in the adjacent healthy tissue in the arrest of the malignant process.

The radio-biologic reaction, then, consists of a direct and a latent process, and it is the combined action of the two which exerts a decided influence upon the healthy surrounding tissue. This defensive mechanism of the neighboring healthy tissue, called by some the "anticarcinomatous reaction," plays perhaps the greater and more important part in the radio-biologic reaction following a suitable dose of radiation. However, following an intensive dose of radiant energy, not only are the malignant cells destroyed to a great extent, but the surrounding tissue itself suffers such severe injury that it thereby sacrifices its defensive mechanism and tissue resistance.

On the basis of recent experiments which will be spoken of later, the defensive mechanism of the adjacent tissues is shown to be of greatest importance in the regression and disappearance of the tumor. Along the same line of investigation, these experiments showed that a carefully selected dose of radiant energy paralyzes the reproductive property of the cancer cell and in this manner impairs the multiplication of the cell without destroying it. A cancer cell which does not multiply any further is no source of danger, especially if the indirect effect of the radiation upon the adjacent neighboring tissue exerts its anticarcinomatous action upon the tumor itself.

This, after all, is the ideal therapy and brings into the foreground the question: When and how are we to take advantage of the most radiosensitive stage of the cancer cell? It is pretty well accepted that the phase preceding and during mitosis of the cancer cell is the most sensitive for radio-biologic attack. Experimentally it has been shown in tissue culture work that the growth of normal cells exceeds that of cancer cells, while the number of mitoses of malignant cells outranks that of normal cells. With transplantable tumors it is feasible to establish uniform experimental conditions, which can be repeated at will. Cramer and other cancer workers report that a sublethal dose of radium, which under ordinary conditions is quite insufficient to destroy cancer cells, will induce complete disappearance of a tumor.

On the other hand, when the tumor is excised after radiation and a new environment is provided by transplanting it into another part of the body, the tumor cells quickly recover from the radiation effects and resume their former rate of growth. This resuscitation of the tumor cells may be observed for three or four days after radiation. In other words, the disappearance of the tumor is not wholly due to the injury of the tumor cells themselves, since they received only a sublethal dose, but to the secondary effect of the surrounding tissue.

Moreover, by inoculating a tumor into each flank and radiating only one tumor, protecting the other flank with lead, the local effect of the tissue resistance is again demonstrated. The radiated tumor regresses, while the tumor in the opposite flank continues to grow as in a normal animal. In other words, it shows definitely that the anticarcinomatous reaction takes place in the surrounding tumor bed and not in the tissues distant from the radiated area. Clinically, this statement can be substantiated as I have never seen the slightest reaction in a metastatic tumor when the primary tumor is irradiated.

This now brings us to the main point of this discussion. It is perfectly true and generally accepted that the greater the number of cells within the tumor undergoing mitosis, the greater is the degree of radiosensitivity of the tissue. This suggests again that the cancer cell is particularly vulnerable to radiant energy during the mitotic phase.

The basis, then, for efficient radiation in the so-called resistant tumors is the excitation of the cancer cells to greater mitotic activity in order to render them particularly sensitive to x-ray and radium. This means the use of small or non-destructive dosage of radiation, remembering that the purpose is to stimulate the

physiologic functions of the cell. By raising the metabolic and biologic functions of the cell, especially in the case of the cancer cell, this tissue becomes increasingly sensitive to the radiant energy and, being stimulated to its greatest activity, becomes exhausted and finally ceases to function entirely. Following this exhaustion or devitalization of the reproductive process of the neoplastic cell, the anticarcinomatous reaction of the surrounding tissue offers active resistance to the progress of the malignancy and subsequently favors the development of the fibroblastic elements. It is of importance to note, however, that each reaction occurs in sequence and culminates at the proper time. In other words, the greater the number of cells within the tumor which are in the phase of mitosis, the more sensitive will be the tissue; also, the longer the intervals between phases of mitosis, the longer will it be necessary to expose the tissues to radiation, if all the cells are to be destroyed selectively. For radiation to be selective it must devitalize and sterilize the cancer cells in doses which do not damage or injure the neighboring unaffected tissues.

It frequently happens that a certain type of cancer might be radiosensitive when localized in one part of the body, and radioinsensitive when growing in another region of the anatomy. This raises the question of whether or not the difference in reaction is due to one particular technic or to the difference in the anatomic topography, and so forth.

In one case, it may be the tumor bed which offers an indifferent soil to the application of the radiant energy; in the other, the anatomic position in which the tumor lies.

It is not my intention in this discussion to point to the many exceptions which favor or resist the best efforts of radiotherapy. However, I wish to draw attention to the possibility of changing, at times, a so-called resistant tumor to a radiosensitive one by means of exciting mitotic activity. In another publication, I have reported several cases which responded favorably to this method and, while I do not claim that every tumor will respond to this method, it seems to me that it deserves at least a trial when other means have failed.

CONCLUSION

I hope that this will dispel the often repeated and unwarranted belief that small and stimulating doses of radiant energy accelerate the growth of a malignant tumor and are therefore contra-indicated. On the contrary, the technic described in this paper has served me satisfactorily to render a tumor, which at the time seemed resistant, to one which behaved subsequently radiosensitive.

THE EARLY DIAGNOSIS OF CARCINOMA OF THE COLON, ROENTGENOGRAPHICALLY CONSIDERED[1]

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From the Department of Gastro-enterology, University of Maryland, and the Department of Roentgenology, Sinai Hospital, Baltimore

CARCINOMA of the colon has long been a subject of much interest to both the internist and the surgeon. Though it is not an uncommon affection, unfortunately the diagnosis is too often not established until late in the course of the disease. The onset is so insidious that frequently medical advice is obtained only when therapeutic measures no longer suffice in accomplishing a complete cure. In many instances months may elapse between the onset of the disease and the time when surgical aid is seriously considered. It is a well established fact that a large number of the growths can be removed and permanent cure brought about if surgical measures are instituted at an early period. The difficulty arises in that tumors in the colonic region are slow in their growth, metastasize late, and, consequently, produce few or no symptoms in their early stages. Thus they are overlooked until complications arise that point to their true nature. It is on this account that every possible attempt should be made to arrive at an early diagnosis, especially since cancer of the colon is of rather frequent occurrence. Intestinal carcinoma occupies the fourth place in frequency as to site of malignant growths, being surpassed in numbers only by the stomach, uterus, and breast.

For the purpose of this study the records of 50 cases of carcinoma of the colon have been reviewed. In these, complete clinical as well as roentgenologic studies were made. Growths occurring below the rectosigmoid area are not considered.

It is my desire to point out the value of x-ray examinations as a means of arriving at an early recognition of this disease. Whenever an individual past middle life, often in the midst of good health, with little or no previous intestinal disturbance, manifests local or general discomfort in the abdomen, associated with disturbances of the bowel in the nature of intermittent or progressive constipation, the possibility of cancer should be suspected and careful investigation should be carried out. A thorough analysis of the history, examinations by digital, rectal, and proctoscopic methods, together with stool investigations, should be made. Early x-ray investigation should never be omitted. Though in the early stages the history and clinical examination are of the greatest importance in pointing to the possibility of this disease, the x-rays may, even at this period, present most definite evidence of its actual presence. This occurs in quite a fair proportion of instances, though it is only fair to state, that, in my experience, occasionally evidence of an early growth was lacking even following roentgenographic examination.

In this series of 50 cases of carcinoma of the colon the growth was observed to be localized as follows: cecum, four cases; ascending colon, three; hepatic flexure, nine; transverse colon, eight; splenic flexure, four; descending colon, three, and sigmoid, nineteen.

In the early period, when the condition is in its incipiency, the diagnosis is often most difficult and even in a fair proportion of such instances the x-ray examination may be misleading. It is important to carry out repeated roentgen studies, especially in doubtful cases. A single roentgen examination should not be relied upon as final. However I would like to empha-

[1] Read before the Baltimore City Medical Society, Dec. 18, 1931.

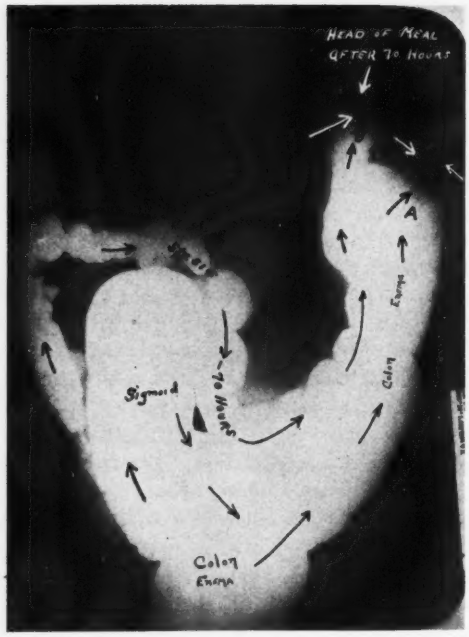

Fig. 1. The combined 70-hour colon stasis and colon enema. The head of the progress meal is seen after 70 hours at the splenic flexure (*B*). Colon enema showed a carcinomatous obstruction in the descending colon below the splenic flexure (*A*).

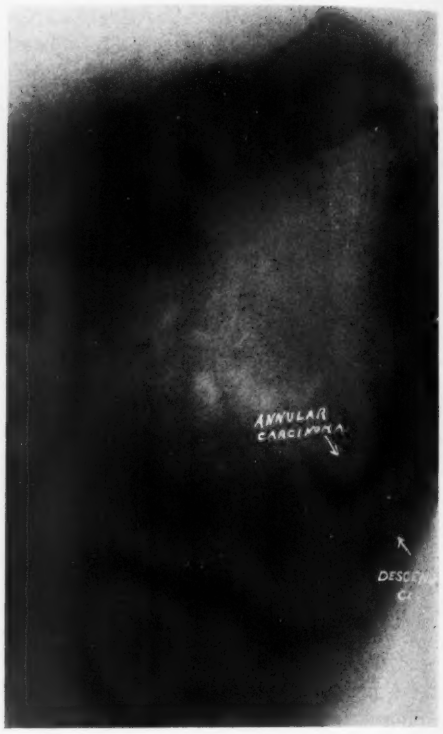

Fig. 2. Colon enema demonstrated an annular carcinoma in the lower descending colon.

size again, at this point, that x-ray evidence of carcinoma in many instances may be elicited long before the clinical manifestations are sufficient to warrant a definite diagnosis.

While it is recognized that the roentgen-ray examination is most important as an aid in arriving at an early diagnosis, we must not be unmindful of the possibility of its errors and limitations. There are often many technical difficulties which may render the diagnosis uncertain and one must exercise great care in evaluating the findings. In certain areas of the colon, especially in the pelvic portion and at the flexures, it is quite possible to overlook a small filling defect, inasmuch as these segments may be obscured by other loops of the bowel. In addition to performing repeated x-ray examinations, it may become necessary to take advantage of special roentgen methods, *viz.*, stereoscopic, oblique, and upright views, which frequently afford the best and most distinctive evidence of the existence of a growth. Negative findings, however, are of little value; in such instances a repeated study at some future date is usually indicated.

The roentgen picture depends in a great measure on the type of lesion, its size, location, and its complications. There are essentially three roentgen methods which are utilized to determine the presence of a colonic growth: (1) the barium colon enema procedure; (2) the combined barium colon enema and air insufflation; (3) the routine gastro-intestinal 24-hour progress meal.

COLON ENEMA

The colon enema, which is usually the method of choice, furnishes the most reliable diagnostic data. It demonstrates the characteristic filling defect produced

by the growth and presents an exact picture of the site, size, and extent of the lesion. It is also invaluable in demonstrating the presence or absence of diseases of the colon other than carcinoma. For this reason it becomes doubly helpful in considering the problem of differential diagnosis.

Preparation of the Patient.—Most roentgenologists prefer to have the patient properly prepared for the examination of the colon. Castor oil may be given 36 hours before the examination, followed in the evening by a cleansing enema. I believe this is an important detail as a routine measure. Some prefer to examine the patient without any previous preparation, inasmuch as such treatment may produce a hypersensitiveness of the bowel, preventing the retention of the enema. In my experience the omission of the morning cleansing enema results in a more satisfactory examination.

The necessity of having a properly prepared medium for the colon enema cannot be too strongly stressed. The barium should be uniformly suspended, of thin liquid consistency and of proper body temperature. Of importance, too, is the rate of flow into the colon. It is essential that it be slow and that it be administered in small amounts, so that each portion of the bowel may be examined with painstaking care under the fluoroscopic screen.

The normal colon does not fill as a straight tube; it will show many contractions, haustral outlines, and bends at the flexures. There are usually temporary delays at the rectosigmoid junction, at the splenic flexure, at the hepatic flexure, and in the ascending colon above the ileocecal valve. A temporary delay in the passage of the column should be carefully visualized and the area palpated with the gloved hand. On account of the frequency of carcinoma involving these areas, the possibility of a small annular growth, which may be palpable, should not be overlooked. A small constricted area, which often may be confused with spasm, is not an infrequent finding in the early stages. The necessity of methodically examining each segment of the bowel independently and palpating each area under the screen is important in the examination of the colon. This procedure cannot be too strongly emphasized.

Fig. 3. The 24-hour progress meal revealed a stasis, with the head of barium at the hepatic flexure. The colon enema demonstrated a carcinomatous obstruction at the hepatic third of the transverse colon.

Filling Defect.—The filling defect varies in size, shape, and regularity, according to the type of carcinoma. It may be small and annular, simulating spasm. It may be smooth and regular, producing a deformity simulating a ring or it may be large and irregular. At times the roentgen defect appears larger than the size of the tumor, due to inflammatory reaction of the surrounding tissue or to a mass of impacted feces. On the other hand it may appear small, yet at operation the neoplasm may be found to be quite large. In the early cases a small narrowed constriction may be interpreted as a haustral contraction. A point of importance, which heretofore has received but little consideration, is a tender area directly above the affected bowel. It is usually localized, persistent, and frequently directs attention to a small filling defect which otherwise might be overlooked. It is of importance to bear in mind that constrictions and organic contractions are not in any way affected by antispasmodics.

Fig. 4. Colon enema showed a carcinomatous filling defect in the cecum.

Fig. 5. The 18-hour progress meal in the same case, showing the carcinomatous filling defect to be more extensive than that observed in the colon enema film. A large carcinomatous mass is also noted directly above the hepatic flexure at arrows.

Palpable Mass.—A palpable mass coexisting with a filling defect is an important sign of the presence of a tumor. Occasionally a mass may be palpated before a demonstrable filling defect is detected. This type of case may escape the roentgenologist's attention. The mass, however, may be the result of a fecal impaction or an associated inflammatory reaction, the cancer growth itself being small in size.

Obstruction.—Obstruction, which may not be observed in the early stages, may be partial or complete. It is usually a late manifestation, occurring most commonly on the left side. In the early stages of the disease, no distention of the bowel is observed; in the late stage, the lumen becomes markedly distended proximal to the growth. The presence of an irregularly distended bowel should direct suspicion to a possible tumor.

Stasis.—Stasis in the colon is observed with great frequency. It may be due to one of many conditions affecting the intestinal tract, the majority of which are benign in nature. When it is present, however, to a more or less marked degree in the 24-hour progress meal, it should be viewed with suspicion. In our series the finding of stasis led to further investigations of the colon which finally resulted, in many instances, in a definite diagnosis of carcinoma. In the late stages of the disease, fixation of the affected colon, perforation, and other complications may be encountered.

AIR INSUFFLATION

Air insufflation of the colon, reported many years ago by Fischer (1), utilizing the combined air and barium enema, and more recently emphasized by Gershon-Cohen (2), and Weber (3), has become a useful procedure in the examination of obscure colon conditions. In the early mucosal lesions it is possible to obtain valu-

able information by this method, which may often result in a definite clue as to the diagnosis. In the later stages of the disease it is also helpful in rendering a clearer and more distinct view of the tumor. Again it is well to take advantage of this method in those instances in which the loops of the bowel are overlapped. Air insufflation may at times reveal a tumor mass, when the usual opaque barium enema may overshadow it.

This procedure is carried out under the fluoroscopic screen. Following the introduction of the barium enema, a film is immediately taken; the patient is then allowed to expel the contents, when another film is made. The patient is further instructed to expel as much of the remainder as possible, and then air is insufflated into the colon. When the bowel is well filled with air, a film is taken for detailed study. I have found this method a most useful procedure in the examination of the colon in those instances in which small growths are suspected.

ROUTINE 24-HOUR PROGRESS MEAL

Barium administered by mouth, as is done in the routine gastro-intestinal progress examination, is sometimes useful in casting further light on the colonic condition. The procedure should always be performed unless some contra-indication exists. The combined progress meal in addition to the barium enema may be of even greater diagnostic aid than either alone. In my own experience one should not place too great reliance upon the colonic findings following the progress meal, unless it is followed by the other procedures. The uneven distribution of the barium throughout the colon may lead to erroneous interpretations. However, at times this procedure gives a clue as to the presence of a possible tumor. This method of examination will not only occasionally reveal a filling defect, but will also outline the proximal site of the tumor, as well as determine other associated conditions of the gastro-intestinal tract.

The presence of a filling defect in carcinoma of the bowel is usually characteristic, but occasionally cancer may be simulated by other conditions. Thus an insufficient amount of barium, fecal matter, spasm, pressure, extrinsic tumors, adhesions, and gas may all produce defects which may mimic carcinoma. These may readily be eliminated by careful technic, cautious interpretation, and by repeated roentgen studies.

In some instances roentgenograms should be obtained in the upright as well as in the prone and supine positions. Stereoscopic and oblique positions are also at times invaluable in demonstrating the true nature of the defect. Hodgson (4) advises the dual exposures for the detection of the filling defect in carcinoma of the bowel. This procedure is carried out by taking two exposures on the same film at two- or three-second intervals.

DIFFERENTIAL DIAGNOSIS

The differential diagnosis between carcinoma of the bowel and other lesions simulating it is at times extremely difficult. Numerous conditions may simulate this affection but none produces the typical filling defect, so constantly present and characteristic of carcinoma. The following important conditions must at times be eliminated: diverticulosis, tuberculosis, benign strictures, benign tumors, impacted feces, adhesions, polyposis, localized ulcerative colitis, and intestinal stasis.

In our series of 50 cases, 30 tumors were surgically removed. Of these, the diagnosis was confirmed by both surgical and pathologic studies. In 20 cases the diagnosis was reached by clinical and roentgenologic studies.

CONCLUSIONS

I have been impressed with the importance—the necessity—of repeated roentgenologic colonic investigation by a number of cases in this series. The roentgen

examination will reveal essentially two main signs which are significant of a new-growth of the bowel, *viz.*, filling defect and obstruction. The filling defect is characteristic in most instances and a diagnosis of carcinoma may be made from it alone. On the other hand, one must make certain that the defect is persistent and that other conditions simulating carcinoma are eliminated. A localized tenderness elicited over a defect is another fairly constant sign suggesting the presence of this lesion. Obstruction is a late manifestation. More often, in the early cases, a retardation to the flow of barium, or canalization of the lumen of the bowel by the growth, or stasis, may be observed. The presence of a palpable mass may not be elicited until late in the course of the disease. The mass is frequently palpated in the area recognized as that of the filling defect. However, the growth may be palpable at times, while at other times it may not. This shifting of the tumor mass is quite characteristic of a colonic new-growth. The necessity of painstaking care in methodically examining each segment of the bowel and the importance of allowing the barium to flow into the colon at a slow rate during the fluoroscopic examination cannot be overemphasized.

The x-ray investigation of the bowel has not been accorded the importance it deserves; it is too often neglected. Roentgenographic examination clearly demonstrates the presence of the lesion, the location, and the degree of involvement. It is also important to bear in mind that much of this detail is not observed following the routine gastro-intestinal examination alone, therefore, many cases of carcinoma of the bowel are overlooked in the early stages. A routine barium enema should always be given whenever the bowel presents evidence of dysfunction.

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ROENTGENTHERAPY IN METASTATIC BONE CANCER, WITH REPORT OF FOUR CASES[1]

By J. ROEMER, M.D., *Paterson, New Jersey*

THAT metastatic bone cancer responds well to high voltage roentgen irradiation is a well-known fact, and there is ample literature to substantiate that view. The foci of bone destruction may be regenerated with new bone formation, which may bring about, in turn, a restoration of normal function to the parts so affected. The patients usually become free of pain within a few days after the treatment has been instituted.

My experience has been confined almost entirely to bone lesions secondary to carcinoma of the breast: I have had occasion to treat only two cases of bone metastases secondary to prostatic cancer, but, in the latter cases, the results were not so good as in the former. I may add that both cases of bone metastases from carcinoma of the prostate had inoperable prostatic tumors. All of the cases which I am presenting were observed in women in whom metastatic bone cancer occurred after radical operation for breast cancer. In these cases there were pronounced bone lesions, as demonstrated by roentgen-ray examination. Undoubtedly more lasting results could be obtained if such cases were treated before metastatic foci are to be roentgenologically demonstrated. In substantiation of this, I wish to cite the case of a woman who developed severe pain in the left hip about one year after mestectomy for carcinoma. Roentgen examination revealed no evidence of any bone pathology. A clinical diagnosis of sciatica was made by the attending physician, and the patient was advised to try spa treatment. Nevertheless pain persisted and nine months after the onset of symptoms, roentgen examination revealed a metastatic focus in the left ischium.

Metastatic foci may also be present in bones without giving any clinical manifestations. It is, therefore, a wise procedure to make routine roentgen examinations of the skeletal tissues, particularly of the pelvis and spine, in all cases of breast cancer. The cases presented here will illustrate what may be accomplished with roentgentherapy.

Case 1 (Figs. 1–3). Mrs. E. H. C., married, aged 41 years, had, in February, 1926, a radical amputation of the right breast for carcinoma. She received no pre- or post-operative radiation. About six months after operation, pain which grew progressively worse, developed in the right hip. On March 18, 1927, the patient came under my observation. Roentgen examination revealed a metastatic lesion involving the right pubis and ischium. She was emaciated, had lost 40 pounds in weight, and was unable to walk. The pelvis was cross-fired with high voltage roentgen radiation, an erythema dose being given to each of three portals of entry. The entire series was given in six successive days. The patient returned for a second series on July 7, 1927. At this time she was feeling well, had regained normal weight, and was able to walk. A roentgenogram taken at this time showed considerable bone regeneration of the focus in the right pubis and ischium. There was a small metastatic focus in the left ischium, which remained quiescent for a period of over three years. Roentgen studies were made at frequent intervals, showing continuous improvement. Twice in 1929 and 1930, the patient received additional small doses (one-half of an erythema dose to each portal). About a month after the first series of roentgentherapy, the patient resumed her occupation as a school teacher and continued until the Fall of 1930. On Oct. 18, 1930, she fell down several steps and sustained a pathologic fracture of the right acetabulum. At this time,

[1] Read before the Radiological Society of North America at the Eighteenth Annual Meeting, in Atlantic City, Nov. 28–Dec. 1, 1932.

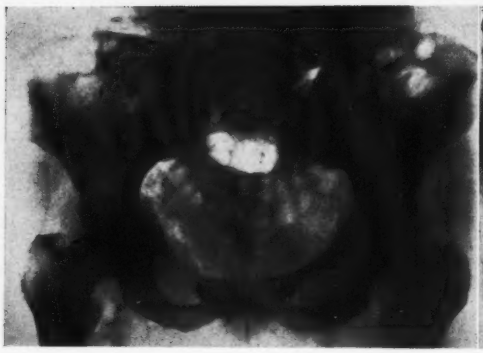

Fig. 1.

Fig. 2.

there were also demonstrated metastatic foci in the left ischium and hip. She went to bed, became very despondent, refused nourishment, and died Jan. 1, 1931.

Case 2 (Figs. 4 and 5). Mrs. P. N., married, aged 46 years, had, in March, 1925, a radical amputation of the right breast for carcinoma. In May, 1925, the patient was referred to me for post-operative roentgen radiation, which was repeated in November, 1925. On Dec. 6, 1926, the patient reported at my office, stating that for the past two months she had had pain in the right hip and was unable to walk without support. Roentgen examination demonstrated metastatic foci in the right ilium and hip. A series of high voltage roentgen radiation was given, and repeated in February, 1927. When the patient reported for the second series, she was free of pain, had gained weight, and was able to walk. Roentgen examination showed retrogression of the lesions. In the Summer of 1927, she returned to her home in Belgium. I received several post-cards from her, the last in December, 1930, telling me that she felt well.

Fig. 3.

Case 3 (Figs. 6 and 7). Miss M. L., single, aged 39 years, had, in September, 1924, a radical amputation of the left breast and, in March, 1927, a radical amputation of the right breast for carcinoma. She received no pre- or post-operative radiation after the first amputation. Five weeks after the second breast was removed, she was referred to me for post-operative radiation, which was carried out. On May 17, 1928, a second course of post-operative radiation was given. At this time there were metastases in the left cervical and supraclavicular glands, to which massive doses of high voltage radiation were applied. On July 19, 1929, the patient complained of pain over the sacrum. Roentgen examination demonstrated a metastatic focus in the sacrum to which high voltage roentgen radiation was given. On Aug. 19, 1929, she reported at my office complaining of pain in the left hip, was limping considerably, and found walking quite painful. She had lost 15 pounds in

Fig. 4.

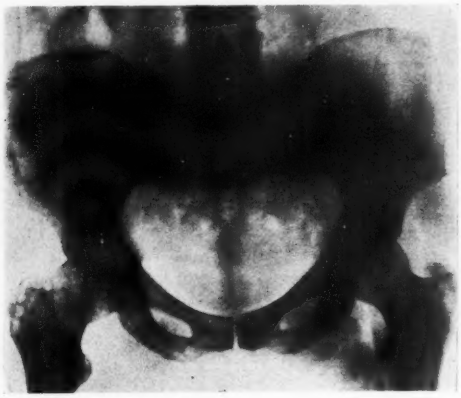

Fig. 5.

weight. Roentgen examination revealed a metastatic focus in the left femur to which high voltage radiation was given. On Jan. 28, 1930, additional smaller doses were applied to both foci, and these were again repeated on Sept. 30, 1930. Roentgen examination made after treatment showed bone regeneration in both foci. In the Summer of 1931, the patient's health began to fail and she died in July.

Case 4 (Figs. 8 and 9). Mrs. M. M., married, aged 36 years, had, in November, 1927, a radical amputation of the left breast for carcinoma. On March 3, 1928, the patient was referred to me and one course of high voltage post-operative radiation was given. In May, 1929, I was requested to make a portable x-ray exami-

Fig. 6.

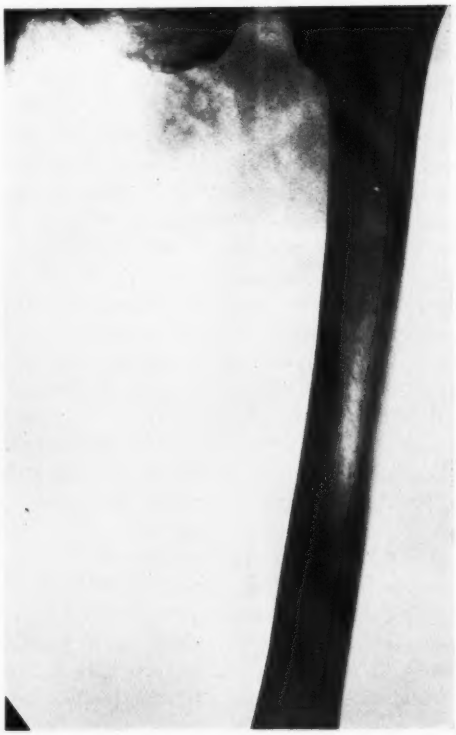

Fig. 7.

Fig. 8.

Fig. 9.

nation of the lumbo-sacral region. The patient had then been bedfast for three months and it was necessary to give her large doses of morphine for the relief of pain. She had lost over forty pounds in weight and her general condition was very bad. Only an anteroposterior roentgenogram was made of the lumbosacral spine as the patient could not be moved to a position for a lateral view. The roentgen examination revealed extensive metastases to the sacrum and fifth lumbar vertebra. On June 22, 1929, she was brought to my office in an ambulance, and, because of the difficulty in moving her, the entire treatment was given in four sessions, four days apart. She received large doses of morphine in order that she might endure the ordeal of being moved. On Aug. 26, 1929, the patient returned for further treatment, and, to my surprise, she was able to walk, had regained over twenty pounds in weight, and felt quite well. Roentgen studies made on that day showed complete bone regeneration of the affected parts. She was given additional small doses in October, November, and December of 1929. When the patient visited my office on Oct. 15, 1929, she informed me that she felt very well and was able to do her house work. She continued thus for over a year, but later developed diabetes mellitus and died in October, 1930, in diabetic coma.

TECHNIC

The technic used is as follows: 215 K.V., 4 ma., filtered with 0.75 mm. Cu and 1 mm. Al, at 50 cm. focal skin distance. With these factors the erythema dose is 86 minutes, when using a portal of entry 20 × 20 centimeters. Daily treatments are given, if possible. In most instances, one-half of an erythema dose is given to one portal of entry at each session. I have encountered very little roentgen sickness in the treatment of metastatic bone lesions.

CONCLUSION

These cases demonstrate that metastatic bone cancer responds favorably to high voltage roentgentherapy. The patients

are made quite comfortable, are able to perform their household duties, and life can be prolonged for several years. Much better results might be accomplished if such cases were subjected to roentgen radiation as soon as clinical symptoms presented themselves, in spite of negative x-ray findings.

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NEW DEVICES

TWO PRACTICAL RADIOLOGIC SUGGESTIONS

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Due to economic considerations, many institutions unfortunately find themselves unable to purchase special viewing boxes for operating room purposes; and since large windows are customarily an integral part of most operating rooms, the roentgenograms to be examined are usually fastened against the window pane, by means of adhesive plaster tabs, and thus illuminated by the transmitted daylight. This procedure is patently not applicable for viewing wet roentgenograms, which necessity not infrequently arises. The

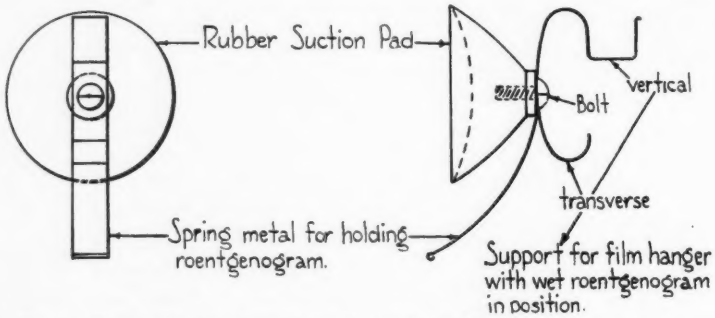

Fig. 1. Front and side views of the device for holding wet and dry roentgenograms in position against the window pane for examination.

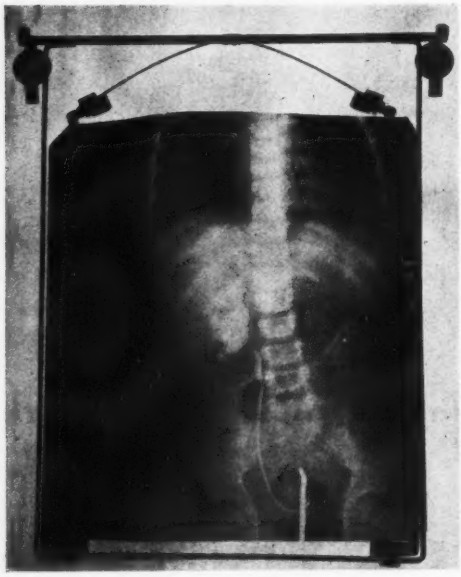

Fig. 2. Showing a wet roentgenogram on its hanger, supported by the two suction pad contrivances. Both wet and dry roentgenograms can be viewed in the horizontal position also. This photograph shows the device mounted upon an operating room window.

manifold disadvantages of the current method have been successfully eliminated since adopting the inexpensive contrivance to be described below.

A coat-hanger appliance equipped with a rubber suction pad can be purchased for a small sum. This permits of secure fastening, by merely pressing the suction pad against the window pane; and contrariwise, can be readily removed or adjusted to any desired position. It is, therefore, adaptable for this special purpose, by bending the metal band of the appliance to the desired shape (Fig. 1). An additional band of brass is fastened firmly in place, by means of the removable hand nut, and the device then serves the dual purpose of holding both wet and dry roentgenograms in position (Fig. 2).

It is an added convenience to employ a drip-pan (positioned beneath the wet roentgenogram), to collect the water from the wet roentgenogram and film hanger. This can readily be constructed from two similar suction pads and a narrow metal tray, hooked into position (Fig. 2).

A convenient calibration graph (Fig. 3) is pasted upon the glass face of the prereading voltmeter. This is drafted from calibration readings. As shown, there is a milliamperage range from 5 to 100, and the various kilovolt peak factors are designated upon the ordinate and abscissa, respectively. The filament

ammeter readings for the various milliamperage factors are likewise on view. The graph is then pasted upon the glass face, and protected by transparent celluloid film. This has proven a neat and practical time-saving device.

DETERMINATION OF THE POTENCY OF X-RAY DEVELOPER

By GEORGE C. HENNY, M.S., M.D., *Philadelphia*

From the Department of Radiology, Temple University Medical School, Philadelphia.

Deterioration of x-ray developer is nearly proportional to the number of square inches of film developed. A simple method for estimating this deterioration is to keep account of the amount of film developed. Charts to be used in the dark room for this purpose are available and the method is recommended by photographic material manufacturers.

R. B. Wilsey (1) recommends a method which makes use of the fact that the time of development bears a definite ratio to the time required for the image to appear after the film is first immersed in the developer. This ratio is known as the Watkins' factor. Pieces of film which have been exposed over part of their surfaces are developed in a tray, measuring the seconds to the first appearance of the image.

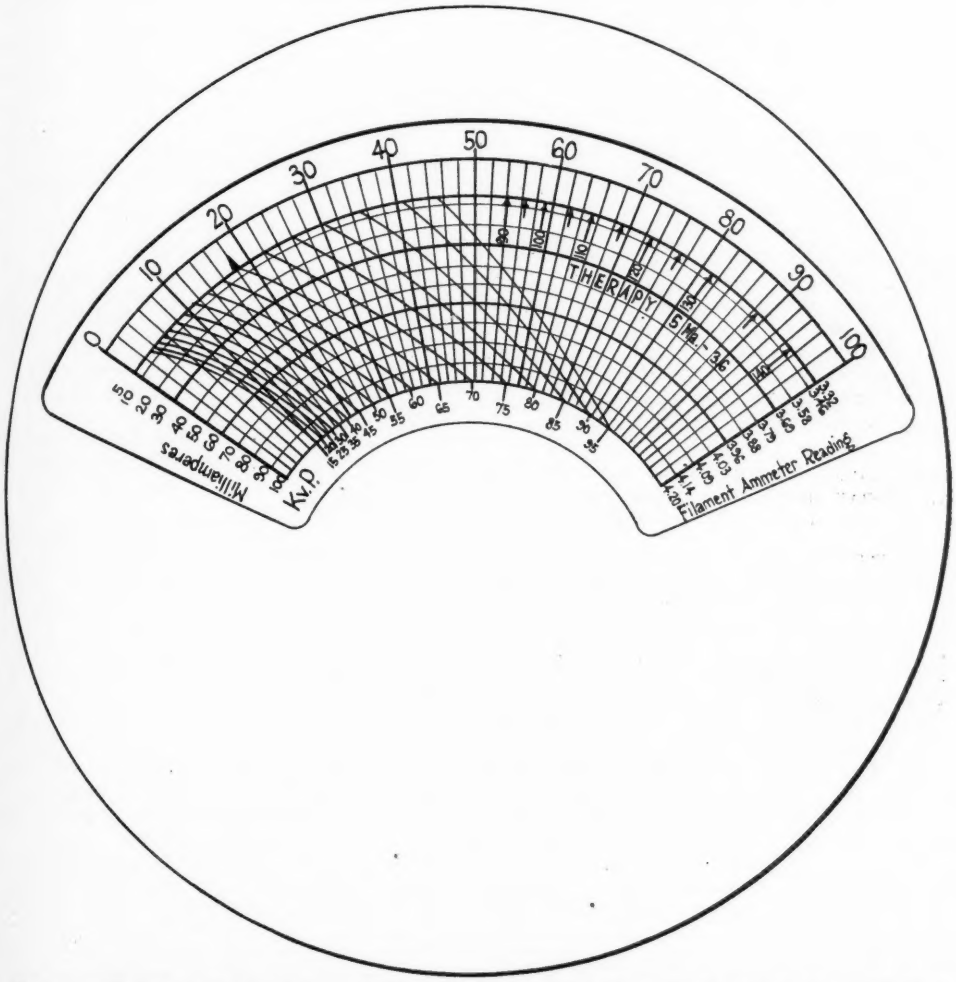

Fig. 3. Calibration chart pasted upon the glass face of the prereading voltmeter. Note the indicator at 18, which is an equivalent to the kilovolt peak readings of 65 for 5 milliamperes; 57 for 30 milliamperes; 38 for 199 milliamperes, etc., with the filament ammeter readings at 3.32, 3.69, 4.20, etc., respectively.

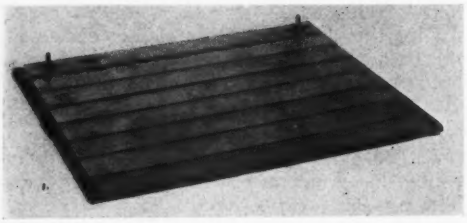

Fig. 1. The aluminum step-ladder placed on the cardboard film holder. There are eight steps, varying from 0 to 7 mm. of aluminum.

Multiplication of this appearance time by the Watkins' factor gives proper development.

Chamberlain and Newell (2) have worked out and described a method of adjusting for changes in the speed of the film as well as for the weakening of the developer with use. Their method is an exact one but since the test films are made with the aid of an accurately controlled therapy machine, it is not available to many roentgenologists. Thanks to the ingenuity of Dr. Robert S. Stone (3), a method is here described in which the test films are exposed with a radiographic machine, such as most roentgenologists have in their laboratories.

Because radiographic apparatus is not equipped with instruments to insure constancy of output from time to time, special precautions are necessary in order that the process of calibrating the developer may be carried over from one test film to the next.

DIRECTIONS FOR DETERMINING THE POTENCY OF THE X-RAY DEVELOPER WITH RADIOGRAPHICALLY EXPOSED FILM

Place a fresh 8 × 10-inch film in an exposure holder (no intensifying screens) under an aluminum step ladder: the ladder we use is made of aluminum sheets 1 mm. thick × 10 inches wide arranged in a staircase running from one to seven thicknesses (Fig. 1). A radiographic tube is placed so that its focal spot is 60 inches above the center of the 8 × 10-inch film. Then, place 2 mm. of aluminum in the filter slots of the tube stand, and expose for 14 seconds at 70 K.V.P., 10 milliamperes.

This film holder is opened in the dark room and about an inch is cut off one of the 8-inch ends of the film. Place this strip horizontally in one-day-old developer at 65° F. for five minutes. (Absolutely fresh developer has been found somewhat variable in our experience.) After being fixed, washed, dried, and labeled, this strip is set aside as the "standard strip" with which subsequent calibration strips are to be compared (Fig. 2).

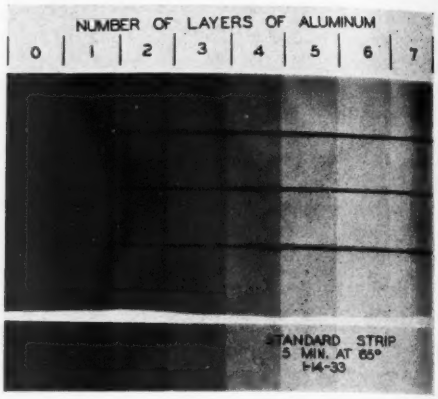

Fig. 2. The finished "standard strip" is shown below. The test strips are cut, as indicated above, from the undeveloped film. After development, they are compared with the standard.

From one to three days later, depending upon the size of the tank in relation to the volume of work, another strip, approximately an inch wide, is cut from the film (which in the meantime has been carefully protected from light and x-rays). This is developed for 5 minutes, placed horizontally in the developer. This strip is then compared with the "standard strip" and may be found light, due to deterioration of the developer. If it is found to be one step lighter than the "standard strip," the developing time is increased by 0.5 minute (or to 5.5 minutes); if two steps lighter than the "standard strip," development time must be increased one whole minute instead of 0.5 minute (or to 6 minutes).

From one to three days later, another strip is removed from the light-tight envelope, developed according to the number of minutes indicated by the last previous strip, and processed in the usual way. This strip is compared, as before, with the "standard strip" and if it is found to be lighter, the developing time must be further increased, 0.5 minute for each step of density-difference on the aluminum step-ladder scale. This process is repeated at intervals until the developing time thus figured reaches 8 or 9 minutes. At about this time in the life of a quantity of developer, one of three things usually happens: staining of the films; loss of contrast, indicated by inconsistent findings at the two ends of the step-ladder density scale when the calibration strip is compared with the "standard strip," or the developer is discarded, even though still working correctly, because of our desire to save time.

One day after the new developer has been

mixed, a strip from a *new* 8 × 10-inch test film—exposed, as described above—is developed for 5 minutes at 65° F. After routine fixing, washing, and drying, it is labeled and used as the new standard for this quantity of developer. If, at the time the new developer is installed, the radiologist finds that he has a considerable supply of test film left, he may use this film in conjunction with the old standard for calibrating the new supply of developer. The "standard strip" is changed only at the time at which a new 8 × 10-inch test film is brought into action. This is essential because, as mentioned above, the control of a radiographic machine is not perfect enough to insure constancy of x-ray output from one test film exposure to the next.

Should the radiologist find that he is running out of test strips before the developer is ready to be renewed, a new 8 × 10-inch test film must be exposed under the aluminum step-ladder, before the last two test strips of the previous series have been used. A strip from this new test film is now developed simultaneously with one of the remaining strips of the previous film, so that both strips receive the development indicated by the previous tests. If the strip of old test film matches perfectly with the old "standard strip," the strip of the new test film can be accepted as a new "standard strip," for it obviously has the same density as it would have attained had it been developed for five minutes in one-day-old developer. If, on the other hand, the strip of old test film does not exactly match the old "standard strip," we still have one more undeveloped strip from the old film, with which to carry on. A new "standard strip" can now be prepared, using simultaneous development of the last strip of old film as a check upon the correctness of the degree of development.

SUMMARY

By using the method described, it is possible to develop all x-ray films to the same degree, from the time the developer is new until it must be thrown out. The proper time for disposal of the developer is also indicated. The method is not expensive and can easily be used by most roentgenologists.

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EDITORIAL

LEON J. MENVILLE, M.D., *Editor* HOWARD P. DOUB, M.D., *Associate Editor*

SCOPE AND TECHNIC OF SOFT-TISSUE ROENTGENOGRAPHY[1]

The systematic investigation of soft tissue by radiographic methods has been attempted spasmodically since the days of pioneers. Technical difficulties, however, have been such that, with a few exceptions, the method has not become a general routine. That soft tissue roentgenography has advanced the diagnostic scope of the roentgenologist there can be no doubt. Moreover, the attention to technical details necessary for this work will result in films of improved quality even when employing the usual technics.

Let us consider briefly the practical value of soft-tissue roentgenography. We demand the same detail in the soft tissues as is necessary in the study of bones; the usual conception of mere outlines of various muscle groups, for instance, will not suffice. It is possible to visualize the normal arteries and veins, particularly at the flexures; the earliest calcification in their walls becomes visible. It is possible to delineate varicose veins. This is particularly significant as regards the deep-seated ones to determine whether or not injection therapy should be used.

Non-osseous tumors form an interesting group of cases. Often valuable information can be obtained as to extent, location, or presence of invasive properties. Muscle structure is well shown. This affords a fine opportunity to study soft anatomy, especially in relation to the bone. Calcification in muscles and rupture, if in a favorable location, can be diagnosed. While of necessity the dense bone detail is unsatisfactory, very early periosteal changes, malignant or inflammatory, become demonstrable; also early callus formation. Gall-bladder shadows following the administration of dye, particularly by the oral method, become denser and there is considerable improvement in the delineation of abdominal masses over the usual technic.

The basic essential principle is to use a low peak voltage and high milliampere-second ratio. The three important limiting factors are: (1) capacity of x-ray tube; (2) thickness of the part, and (3) speed necessary to stop motion. In general, a 250 to 300 milliampere-second ratio, keeping the kilovoltage as low as possible consistent with adequate penetration, is best. This means for the majority of work 100 ma. for three seconds, the K.V.P. to be varied according to the thickness of part. A decrease in the time factor must of necessity mean an increase of the load on the tube. The use of a high milliampere-second ratio improves soft-tissue detail even if the Potter-Bucky diaphragm is used.

A word as to machines: Any outfit having an honest rating of 100 ma., with autotransformer control of not more than 2.5 K.V.P. steps should suffice. The finer the regulation of the machine the better will be the results. A fluctuating supply line will interfere with consistent results. Intensifying screens are used if soft-tissue detail alone is desired. If bone and soft tissues together are to be studied, film holders are employed. Single screens are preferable, although excellent work can be done with the double ones. Too high speed is not desirable as ensuing grain may detract from the diagnostic value of the radiograph. Uniformity of speed, however, is quite important. If more than one cassette is used, the two should be matched for screen speed.

A "contrasty," brilliant, clean base film, such as is now made by most of the manufacturers, gives the best results. Stale film should not be used. The presence of fog from whatever cause is absolutely ruinous to good results. The method of development is very important—solutions must be fresh and at a correct temperature to ensure freedom from fog or stain. A strict time-and-temperature system is quite unsuited to this type of radiography: it has to be by sight. A knack is required which is readily gained after a little experience. In the New York Hospital a small dark-room has been installed to take care of this type of work.

Soft-tissue technic is specialized work and requires particular interest from the roentgenolo-

[1] Read before the American Congress of Radiology, at Chicago, Sept. 25–30, 1933.

gist, who should either make the roentgenographs himself or train a technician, to make certain of the small details necessary for success. Indeed, the ability to do this work with precision is a good index of the degree of organization of the department or office. In positioning the patient the part to be demonstrated must not be obscured by bone which will blot out the detail. A knowledge of soft as well as osseous anatomy, together with a little ingenuity, will be necessary.

In determining the proper penetration to be used it is convenient to divide an extremity into three zones, as follows: Zone 1, skin and subcutaneous structures; Zone 2, muscles and periosteum; Zone 3, solid osseous structures. Each of these zones demands a different penetration. For instance, if it is desired to examine a subcutaneous hematoma, less penetration is required than for muscular detail. In the case of an individual in whom there is considerable difference in size of muscle mass, more penetration is required for the upper portion than the lower, if detail in Zone 2 is wanted. Until facility in judging exposure is acquired trial exposures over a small area are advisable.

No filter is used in non-Potter-Bucky diaphragm work. This, together with the high milliampere-second ratio, increases the liability to a dermatitis. The factor of safety, however, is sufficient if due care is exercised.

A word as to the viewing of the processed radiograph: For the best results the film should be studied under an illumination of varying intensity as well as color, that is, by a yellow and then by a blue light. If this is done, the utmost can be obtained from the film.

Conclusions.—Soft-tissue roentgenography greatly enlarges the diagnostic scope of the roentgenologist and will well repay him for the slight extra effort required.

JOHN R. CARTY, M.D.

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COMMUNICATIONS

INDIANA ROENTGEN SOCIETY

The seventh annual meeting of the Indiana Roentgen Society was held in Indianapolis on Feb. 22, 1934, upon which occasion John T. Murphy, M.D., of Toledo, Ohio, addressed the Society.

The following officers were elected: *President-elect*, D. C. McClelland, M.D., of LaFayette; *Vice-president*, Ross Tracy, M.D., of Anderson, and *Secretary-Treasurer*, James N. Collins, M.D., of Indianapolis.

MINNESOTA RADIOLOGICAL SOCIETY

The Minnesota Radiological Society held its winter meeting at the University Hospital, Minneapolis, on March 10, 1934. The following program was presented:

1. Roentgenologic Studies of Multiple Births, Leo G. Rigler, M.D.
2. The Incidence of Paraesophageal Hernia in Pregnant Women, John B. Eneboe, M.D.

Discussed by Walter H. Ude, M.D.

3. Radiation Effects on Tissue Cultures of Lymph Nodes, Joseph T. King, M.D., and K. W. Stenstrom, Ph.D.
4. The Ventriculogram in a Case of Tuberosclerosis, N. J. Berkwitz, M.D., and Leo G. Rigler, M.D.
5. Benign Strictures of the Stomach, Jacob Sagel, M.D.
6. Observations on the Radiation Therapy of Carcinoma of the Breast, K. W. Stenstrom, Ph.D.

Discussed by E. T. Leddy, M.D.

7. Histologic Studies of Human Liver after Injection of Thorium Dioxide Sol, Leo G. Rigler, M.D., and Rudolph Koucky, M.D.
8. The Epiphysis of the Tuberosity of the Fifth Metatarsal, John B. Eneboe, M.D.

Discussed by John D. Camp, M.D.

9. Roentgen Observations on Acute Amebic Colitis, Kano Ikeda, M.D.
10. Roentgen Observations on Early Tuberculosis in Young Adults, Leo G. Rigler, M.D.

Discussed by M. B. Hanson, M.D.

11. Case Reports

(*a*) Spontaneous Gastro-enterostomy, C. N. Borman, M.D.

(*b*) Lympho-epithelioma, C. O. Hansen, M.D.

(*c*) Trichobezoar, Oscar Lipschultz, M.D.

(*d*) Osteomyelitis of the Patella, Jacob Sagel, M.D.

(*e*) Gall-bladder Obstruction of the Small Intestine, C. N. Borman, M.D.

Addresses: The American Board of Radiology, B. R. Kirklin, M.D.; Observations on the Diagnosis and Treatment of Malignancy, William T. Peyton, M.D.

LECTURESHIP IN RADIOLOGY

The Minnesota Radiological Society wishes to announce the establishment of an annual lectureship in Radiology in honor of Russell D. Carman, M.D. This is to be known as the Russell D. Carman Memorial Lecture, and will consist of an address by a prominent radiologist at the annual meeting of the Minnesota State Medical Association before the general assembly of that body.

The first in this series of lectures will be given by A. B. Moore, M.D., of Washington, D. C., at the meeting of the Minnesota State Medical Association in Duluth, Minnesota, July 16, 1934. In addition, at this meeting, Donald C. Balfour, M.D., of Rochester, Minnesota, will deliver an address on the life of Dr. Russell D. Carman.

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J. E. Habbe, M.D., of Milwaukee
H. W. Hefke, M.D., of Milwaukee
Davis H. Pardoll, M.D., of Chicago
Ernst A. Pohle, M.D., Ph.D., of Madison, Wis.
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CONTRAST MEDIA

The Patency of Biliary Ducts: Determined by Radiopaque Oil Injected through a T-tube Previously Placed in the Common Bile Duct for the Purpose of Prolonged Drainage. E. Starr Judd and J. Roberts Phillips. Surg., Gynec. and Obst., November, 1933, LVII, 668–671.

The authors discuss the study of the biliary tract by means of the x-ray during the injection of lipoidol through the T-tube employed for drainage of the common bile duct. They also report a series of four cases illustrating the value of this method.

Following the suggestion of Ginsburg and Benjamin, Gabriel injected lipiodol through the T-tube that had been placed in the common bile duct for drainage. It is possible by this method to prove definitely the patency of the ducts while the T-tube is still in position. In some cases the medium reaches the smaller biliary passages and thus affords an opportunity to study these structures.

The authors select, for this procedure, only ambulatory patients who have not recently had chills or fever. The lipiodol is injected while the patient is under the fluoroscopic screen, the passage of the medium through the biliary tract being noted. After the fluoroscopic examination more lipiodol is injected through the T-tube and a plain film of the abdomen is made. Although the authors have employed in some cases as much as from 15 to 20 c.c. of the oil, no ill effects were noted in their series of 40 cases.

J. N. Ané, M.D.

DOSAGE

Comparison of the Doses Applied with the Protracted Fractional Dose Method and the Single Dose Method. H. Wintz. Strahlentherapie, November, 1933, XLVIII, 535–551.

In order to compare the doses applied with the protracted fractional dose method and the single dose method, Coutard's technic was used in treating carcinoma of the cervix. The doses were calculated and checked by measurements on the phantom and on the patients. The ratios of the doses given with the single dose method and Coutard's method were as follows: For the skin, 1:2; for the carcinoma, 1:2.4; for the intestines, 1:2.2, and for the connective tissues, 1:1.4. The author states that the doses effective in the tumor are so high that its destruction can be explained by that fact. He does not believe that the good results obtained with the Coutard method are due to an increased radiosensitivity because of the distribution of the dose. He still favors the single dose method.

Ernst A. Pohle, M.D., Ph.D.

Clinical Experience with the Protracted Fractional Dose Method in Inoperable and Recurrent Malignant Tumors of the Genital Organs and in Cancer of the Breast. Paul Schumacher. Strahlentherapie, 1933, XLVII, 338–343.

The following technic is used: 210 K.V., 2 mm. Cu, half value layer in Cu 2.1 mm., 2.5 ma., 50–80 cm. F.S.D., 10 × 15 and 20 × 20 cm. field. The surface dose given amounts to 200 r. The total doses effective in the tumor vary between 2,000 and 3,000 r. In the beginning of the treatment the author finds little reaction. Later on, there is definite loss of weight, the leukocytes drop to 3,000 and less, at which point the treatment should be interrupted. Erythema appears after from 1,600 to 1,800 r. No late injuries have been observed up to a period of two years following the treatment. Severe late acute reactions may occur occasionally in the skin and also in the intestines.

Eight inoperable and recurrent carcinomas of the uterus were treated. Of these, three responded well, three others did not respond, and two grew worse during the treatment. Two cases with small recurrences in the parametrium disappeared following application of 2,100 and 2,300 r, respectively. Three other cases with involvement of the entire small pelvis did not respond. The remaining five were patients who had received radium and single high doses of x-rays. They did not respond.

Better results were obtained in 12 cases of inoperable carcinoma of the ovaries. The entire abdomen received doses of from 2,300 to 2,700 r during a period of from 7 to 10 weeks. The tumors begin to regress, usually during the third treatment week.

The same method was also used in 10 cases with recurrent carcinoma of the breast. Some of these responded well but the time of observation is still too short to permit one to draw definite conclusions. Sarcoma in the pelvis does not seem to respond at all, according to the author's experience.

In conclusion, he urges great caution in the application of this method because too high doses in too short a time may lead to disastrous results.

Ernst A. Pohle, M.D., Ph.D.

The Slow Course of Lymphogranulomatosis after Roentgentherapy. M. Goldstein and S. S. Zuckermann. Röntgenpraxis, June, 1933, V, 410–413.

Two cases of lymphogranulomatosis (Hodgkin's disease) of unusually long duration of life are reported. One case became symptom-free for seven years after roentgen treatment, given in fractionated doses. The patient died soon after an acute recurrence. In another case the disease was kept under control for ten years and the patient's condition at the time of the last examination was satisfactory. Successful roentgentherapy may achieve complete disappearance of the granulomatous nodes.

The fractionated method seems the more advisable with one-fourth to one-third of an S.E.D. as the single dose and from 100 to 150 per cent altogether over each field. Results often depend on the stage of the disease and are naturally better in its early stages. Roentgen rays act selectively on the nodes and, with the right judgment and correct treatment, cases which

cannot be influenced by irradiation should become fewer in number.

H. W. HEFKE, M.D.

Roentgen Treatment of Uterine Fibroid and Uterine Hemorrhage with One Abdominal Field. Arnold Püschel. Strahlentherapie, 1933, XLVI, 346–354.

Based on the analysis of 88 patients, the author recommends the use of one abdominal field 10 × 15 sq. cm. at 40 cm. F.S.D. through 0.5 mm. Cu, H.V.L. in Cu, 0.95 mm. The surface dose may be as high as 600 r.

ERNST A. POHLE, M.D., Ph.D.

Tables on the Absorption of Roentgen Rays. H. Küstner and Friedrich Voges. Strahlentherapie, 1933, XLVI, 585–600.

This series of tables facilitates greatly the calculation of the absorption coefficients and the coefficient of weakening of roentgen rays.

ERNST A. POHLE, M.D., Ph.D.

THE EYE (THERAPY)

X-ray Therapy in Tuberculous Diseases of the Eye. Wolfgang Hoffmann. Strahlentherapie, December, 1933, XLVIII, 790–796.

The author believes that radium is superior to roentgen rays in the treatment of tuberculous diseases of the eye. All 16 cases of tuberculosis of the conjunctiva, published in the literature, were cured by radium treatment. Four were treated by gamma rays, the others by beta rays. In tuberculous diseases of the posterior eye, he used gamma radiation exclusively. The treatment was given with 30 mg. of radium distributed in 15 screens filtered through 0.2 mm. Pt. They were placed in a 1 mm. brass case of a 0.5 × 0.8 cm. surface measurement. Diseases of the anterior part of the eye were treated at a distance of 1 cm., and a total of 72 mg.-hr. were given during a period of 3 days. For the posterior part of the eye, the distance was increased to 2 cm., the dose to 288 mg.-hr., given over a period of from 4 to 6 days. Sensitive patients received half of the dose and, if necessary, the treatment was repeated after one week. The clinical results, in 159 cases treated during the last five years, were very satisfactory.

ERNST A. POHLE, M.D., Ph.D.

GALL BLADDER (NORMAL AND PATHOLOGIC)

Dextrose as an Adjunct for Oral Cholecystography. Pfeiffer. Röntgenpraxis, April, 1933, V. 297–299.

Oral cholecystography is reported as showing a rather high percentage of failures; in the author's experience a non-functioning gall bladder was found too often in persons with a normal liver and gall bladder. Even if some of the failures may be explained by the lack of co-operation of the patient, some of them must be attributed to other causes. Factors which might be responsible for non-filling of a normal gall bladder are: precipitation of the contrast material by the gastric juice, poor resorption of the dye in the small intestines, or insufficient fixation of it in the liver cells (insufficient excretion by them). The first factor has been overcome by taking the dye with fruit juices or combining it with fruit acids. The two other factors, poor absorption from the intestine and poor function of the liver cells, must be responsible for most of the failures. In the author's opinion a liver cell loaded with glycogen is better able to fixate and excrete the dye than one poor in glycogen. For that reason, 35 gm. of dextrose diluted in a glass of water were given shortly after the drinking of the dye. It seems important to have the patient drink the dye slowly (from ten to fifteen minutes is about right), as rapid drinking seems to cause much more nausea and vomiting. After this technic was initiated the results immediately became much better and are now satisfactory. In the average case the gall-bladder shadow was larger and more intense.

Some Italian authors have used 40 per cent glucose solution intravenously in combination with intravenous cholecystography and have noticed a similar improvement in their results.

H. W. HEFKE, M.D.

GASTRO-INTESTINAL TRACT (DIAGNOSIS)

Lymphatic Hyperplasia of the Gastric Mucosa in Lymphatic Leukemia. M. Lüdin. Röntgenpraxis, November, 1933, V, 816–819.

A case of lymphatic leukemia, with marked lymphatic hyperplasia of the gastric mucosa, is described. Roentgen examination of the stomach showed irregular, broken contours of the greater curvature. This appearance was first explained by the pressure of enlarged glands on the stomach, but further study showed that the mucosa relief was definitely changed and irregular, a fact which indicated an involvement of the stomach itself. At autopsy, the perigastric glands were found to be much enlarged, the gastric mucosa was thickened, the folds were wide, and in some places the mucosa was one centimeter thick. Microscopic examination showed lymphatic involvement of the entire wall of the stomach.

H. W. HEFKE, M.D.

Chronic Cicatrizing Enteritis: Regional Ileitis (Crohn): A New Surgical Entity. Franklin I. Harris, Glenn H. Bell, and Harold Brunn. Surg., Gynec. and Obst., November, 1933, LVII, 637–645.

The authors suggest the term "chronic cicatrizing enteritis" for that condition of the intestinal tract previously referred to by Crohn, Ginzburg, and Oppenheimer as "regional ileitis." Regional ileitis was defined by these writers as "a disease of the terminal ileum, affecting young adults and characterized by a sub-acute or chronic necrotizing and cicatrizing in-

flammation of all the coats of the ileum which frequently leads to stenosis of the lumen, and is often associated with fistula formation and a tumor mass in the right lower quadrant." In the authors' experience, this condition may affect the jejunum as well as the terminal ileum, and they report such a case.

The pathology in the earlier stages is confined to the mucosa of the small bowel, most frequently the ileum. This consists of small ulcerated areas on the mesenteric border of the small intestine. The submucosa and, to a lesser extent, the muscularis, are considerably thickened as a result of hyperplastic and exudative changes. This produces varying degrees of stenosis, and since the intestine, proximal to the involved segment, becomes dilated there may be alternating areas of constriction and dilatation. At a later stage, the exudative reaction is replaced by a marked fibrosis which extends into the mesentery of the involved segment of bowel. In the terminal ileum, the most intensive inflammatory reaction occurs in the region of the ileocecal valve. As a result of the pathologic changes, Bauhin's valve may be converted into a rigid diaphragm with a small opening. The ileocecal stenosis, and the hyperplastic terminal ileum, correspond to the mass often found in the lower right quadrant.

Crohn and his associates recognize four types of this disease: (1) Acute, with signs of intra-abdominal inflammation; (2) symptoms of ulcerative colitis; (3) stenosis, with symptoms of intestinal obstruction; (4) fistulous stage.

It is almost impossible to distinguish acute appendicitis from those cases with signs of acute intra-abdominal inflammation. Pain and tenderness in the right lower quadrant, fever, leukocytosis, and a mass in the right lower quadrant may be present.

In the second type, there is a history of diarrhea associated with peri-umbilical and lower abdominal pain. Pus, mucus, and visible blood may be present in the stools. Constant fever, loss of weight, and secondary anemia are noted during the course of the disease, which may last as long as a year. In the majority of cases, the patient passes gradually into the stenotic phase of the disease.

The stenotic type, which is more frequent, is marked by symptoms of partial obstruction. Violent cramps, vomiting, visible peristalsis, distention, and a palpable mass may be noted. It is possible for the stenotic phase to be the first manifestation of the disease.

Fistual formation marks the fourth or fistulous stage. Practically diagnostic of the disease is a fistula in the abdominal wall, persisting and appearing after operation for a supposed acute appendicitis and the removal of an innocent appendix. These fistulæ usually occur months after the operation and after the original incision has healed. The first sign is usually an abscess on the abdominal wall which, on being opened, leads to the intestines.

Radiologic examination in these cases may show delay in the small intestines early in the disease. Later, in the stenotic phase, definite evidence of obstruction, with dilatation of small bowel loops, may be noted. While the symptoms may suggest ulcerative colitis, a barium enema will not reveal the pathology which will be disclosed by serial roentgenologic examination.

The treatment of this condition is surgical, medical treatment being only supportive and symptomatic.

J. N. Ané, M.D.

A Further Contribution to the Roentgenologic Diagnosis of the Small Intestines: The Flexura Ultima. Th. Rövekamp. Röntgenpraxis, June, 1933, V, 413–422.

Anatomical variations of the last portion of the ileum are numerous. Fixation of the last loop to the cecum (by adhesions or congenital bands) can be diagnosed only when this part of the small intestines is found at repeated examinations to be fixed. A change in tonus may lead to abnormal situations, kinks, elongation, narrowing, and the like. In the case of a cecum mobile, one may see the last small intestinal loop in many different positions. In most cases there are no symptoms, but occasionally one must attribute the symptoms of a patient to this anomaly. Pathologic changes in the appendix may cause fixation of the last loop of the ileum by adhesions. Tuberculosis or dysentery are other causes for immobility of this portion of the small intestine, even without fixation of the cecum. Of course, abdominal tumors will displace the last flexure. It has not been possible to diagnose tuberculosis of the small intestines by examining roentgenologically the mucosa-relief. Tuberculosis of the cecum is usually associated with it and can be demonstrated rather easily.

H. W. Hefke, M.D.

GRENZ RAYS

Seven Years' Experience with Grenz-ray Therapy of Lupus. G. Schulte. Strahlentherapie, December, 1933, XLVIII, 690–697.

The author relates his experience with Grenz-ray therapy of lupus vulgaris. He recommends 2,000 to 2,500 r (10 K.V., 10 ma., 0.5 cm. F.S.D.), to be repeated after from 8 to 14 days. It is necessary to produce marked reactions. He has seen no untoward results after these high doses. A combination with ultra-violet radiation is recommended.

Ernst A. Pohle, M.D., Ph.D.

Grenz Rays in Tuberculosis of the Skin. B. Spiethoff. Strahlentherapie, December, 1933, XLVIII, 685–689.

The author has obtained good results with Grenz rays in large doses (4,600 r, 9 K.V., 2.5 cm. F.S.D., H.V.L. in Al, 0.015 mm.). He stresses the importance of using "soft" radiation. It is possible to apply as much as 22,000 r over small areas. A combination with infra-red rays proved very effective.

Ernst A. Pohle, M.D., Ph.D.

New Constructions in Grenz-ray Technic. Heinz Berger. Strahlentherapie, January, 1934, XLIX, 141–149.

The author describes several new Grenz-ray tubes and types of apparatus on which this tube can be operated.

ERNST A. POHLE, M D., Ph.D.

First Experience with Air Cooling in Grenz-ray Apparatus. W. Gertz. Strahlentherapie, 1933, XLVI, 775–779.

The author reports briefly his experience with air-cooled Grenz-ray tubes and discusses the cost of operation.

ERNST A. POHLE, M.D., Ph.D.

Spectrographic Studies on Different Types of Grenz-ray Tubes. O. Gfrörer and Heinz Berger. Strahlentherapie, November, 1933, XLVIII, 570–577.

Spectral studies on three makes of Grenz-ray tubes lead the authors to the conclusion that the half value layer in aluminum is not an accurate factor to express quality. The exact determination of the tube potential is more reliable.

ERNST A. POHLE, M.D., Ph.D.

HEART AND VASCULAR SYSTEM

The Roentgen Findings in the Case of a Large Aneurysm of the Apex of the Heart. E. E. Bauke. Röntgenpraxis, June, 1933, V, 444–448.

Myomalacias which lead to circumscribed bulging of the heart silhouette may be demonstrated roentgenologically. If this aneurysm-like bulging is present on the anterior or posterior aspect of the heart, a correct roentgen diagnosis may be possible only when it is large. Comparatively few cases of this kind have been described in the literature. In the author's case, a man 55 years of age with a typical history of angina pectoris and infarction of the heart muscle, a roentgenologic examination showed a round, well circumscribed bulging at the apex of the left ventricle, the size of a small apple, which pulsated with the left ventricle. An electrocardiogram showed changes typical of coronary disease and infarct. At autopsy the roentgenologic diagnosis was confirmed.

H. W. HEFKE, M.D.

RADIATION EFFECTS

Changes in Membranes under X-ray Exposure. Josef Grauer Strahlentherapie, January, 1934, XLIX, 118–131.

Saxe (*Strahlentherapie*, 1931, XL, 125) reported the results of his experiments regarding the effect of roentgen rays on membranes. He observed a definite change in permeability, depending upon the dose. The author undertook a series of control experiments, but could not confirm Saxe's findings.

ERNST A. POHLE, M.D., Ph.D.

The Influence of Radium and Roentgen Rays, Ultraviolet Light, and Heat on the Cell Division in Warmblooded Animals. Jeno Juul and Tage Kemp. Strahlentherapie, November, 1933, XLVIII, 457–499.

Radium and roentgen exposure of tissue cultures of chicken fibroblasts produce a marked decrease of the number of mitoses during the first hour. Following a certain interval,the number of mitoses increases again. Gamma rays and x-rays produce identical results. There is no latent time. Similar changes can be observed after the tissue cultures are exposed to ultraviolet rays emitted by a quartz mercury vapor lamp. A marked drop in the number of mitoses is also observed, if the temperature of the tissue cultures has been increased from 47 to 50 degrees centigrade. An analysis of the experimental results lead the authors to the conclusion that irradiation chiefly attacks the chromatin of the nucleus, while the effect of the higher temperature is due to changes in the protoplasm.

ERNST A. POHLE, M.D., Ph.D.

The Effect of Alpha Rays on Tissue Cultures. H. C. Andersen and M. Fischer. Strahlentherapie, November, 1933, XLVIII, 500–507.

Tissue cultures of fibroblasts were exposed to alpha rays. The inhibition of growth increased with increasing dose. There was a definite latent time. Even the smallest doses did not produce a stimulating effect.

ERNST A. POHLE, M.D., Ph.D.

Radiobiology of Tissue Cultures. Hildegard Vollmar and B. Rajewsky. Strahlentherapie, November, 1933, XLVIII, 508–518.

The authors point out a number of errors which might creep into the results of experimental work with tissue cultures. If a culture is, for instance, slightly heated, an inhibition of growth may result, and suggest an increased radiosensitivity. The relative size of the piece of tissue and the "hanging drop" also influence the degree of radiosensitivity. The threshold values for injurious doses of ultra-violet light vary greatly for different types of tissue cultures.

ERNST A. POHLE, M.D., Ph.D.

RADIATION INJURIES

Post-operative Treatment of Roentgen Carcinoma. Karl Gütig. Strahlentherapie, 1933, XLVII, 390–392.

A roentgen carcinoma was removed from the hand of an x-ray technician, the wound healing except for a spot the size of half a dollar, upon which all known methods failed. The author then tried a 10 per cent boric acid-adrenalin ointment which led to prompt healing of the defect in a few days. He suggests, therefore, that this ointment be given a trial in similar cases.

ERNST A. POHLE, M.D., Ph.D.

Clinical Illustrations of Deep Roentgen-ray and Radium Burns. John Staige Davis. Am. Jour. Roentgenol. and Rad. Ther., January, 1933, XXIX, 43–78.

This article is profusely illustrated with films of patients before and after operative treatment for various degrees of severe x-ray reactions. The author groups these cases according to location on the head and neck, trunk, and extremities. According to present-day standards of safety, many of these cases obviously represent careless radiation therapy technic or unthinking diagnostic fluoroscopic work. It is the writer's belief that the only rational method of treatment is complete excision of the damaged tissues, with tissue-shifting to fill the defect thus made. The illustrations indicate the excellent cosmetic results which may be obtained in addition to relief of the pain and disfiguration which usually accompany the unhealed so-called "burn."

J. E. Habbe, M.D.

Abnormal Growth of Hair Following Roentgen Examination. Herbert Schlathölter. Strahlentherapie, 1933, XLVII, 393–395.

The author described the history of a man who, in 1904, when 16 years old, had an x-ray film made of the cervical spine. He also was fluoroscoped seventeen or eighteen times afterwards. He developed a severe reaction which was treated by ointments. In the exposed field (posterior shoulder region) a marked pigmentation appeared, followed by growth of hair. Photographs show this rather interesting phenomenon.

Ernst A. Pohle, M.D., Ph.D.

The Problem of X-ray Injuries Following the Treatment of Tuberculosis of the Skin. Karl Hoede. Strahlentherapie, December, 1933, XLVIII, 680–684.

The author studied the question of late injuries following x-ray therapy of skin tuberculosis. He comes to the conclusion that, if treatment is applied properly, there will be no late injuries. The publication of such cases should not, therefore, lead to the discontinuation of roentgen therapy in tuberculosis of the skin. He has observed patients who were treated during childhood, without for many years seeing any undesirable results. There seems to be no connection between carcinoma growing in a tuberculous skin area and previous roentgen therapy.

Ernst A. Pohle, M.D., Ph.D.

RADIUM

A Case of Chorio-epithelioma of the Vagina Cured by Radium. Felix Gal. Strahlentherapie, 1933, XLVII, 322–325.

The author reports a case of chorio-epithelioma in the vagina in a woman 37 years of age. Local radium application and x-ray deep therapy to the pelvis led to a clinical cure.

Ernst A. Pohle, M.D., Ph.D.

Five-year Results of Suprapubic Radium Implantation into Bladder Tumors. Edward L. Keyes. Surg., Gynec. and Obst., February 1, 1934, LVIII, 233–237.

The author reviews the case histories of his series of bladder tumors treated by suprapubic radium implantation and analyzes the 5-year results in this group. The mortality for the whole series was 61 per cent, and the 5-year cures, 29 per cent.

The cases had been divided previously into the following groups: Papilloma and Grade I, Grade II, Grade III, Grade IV. This classification was based on a combination of clinical and pathologic observations, somewhat similar to that employed by Dr. Barringer in 1928.

The prognosis in Grade III was bad and that in Grade IV even worse. In Grade III the author obtained 23 per cent 5-year controls, and in Grade IV only one patient survived for a period of 6 years and then died of cancer.

While no attempt is made to compare radon implantation with other forms of surgical procedures, such as resection of the bladder, the use of radon has the following advantages: No ureteral re-implantation has to be done; the operative mortality is much lower, and the stay in the hospital is shorter.

Many of the patients of this series were treated with a lower dosage of radium than employed to-day by the author. The former 1 millicurie or 1.5 millicurie radons have been replaced by 2 millicurie radons.

J. N. Ané, M.D.

The Permeability of the Skin for Radium Emanation. W. Santholzer. Strahlentherapie, November, 1933, XLVIII, 519–534.

The radio-activity of the blood, following a radioactive bath, was determined in blood specimens of 40 c.c. each. From five tests, the author concludes that the skin is permeable for radium emanation. A theoretical explanation is offered.

Ernst A. Pohle, M.D., Ph.D.

THE SKULL (DIAGNOSIS)

Cerebral Hemiatrophy, with Homolateral Hypertrophy of the Skull and Sinuses. Cornelius G. Dyke, Leo M. Davidoff, and Clement B. Masson. Surg., Gynec. and Obst., November, 1933, LVII, 588–600.

The authors report a series of nine cases, with a clinical picture of infantile hemiplegia which showed roentgenologic changes in the skull.

There is apparently no uniformity of etiology, for, of the nine patients included in this report, four showed a sudden onset post-natally with fever, convulsions, and hemiplegia; two occurred as a result of trauma received at birth; one was of pre-natal origin; in another, the symptoms began after a severe fall at the age of one year, and the remaining case followed partial asphyxiation, due to a tight umbilical cord around the

neck. The pathologic processes noted consisted of focal cerebral defects of varying extent.

Considerable variance may, likewise, be exhibited in the clinical picture of these cases. The convulsions and hemiplegia may occur immediately or some time after the trauma or acute infectious onset. During the course, the seizure may change in character. Considerable uniformity occurs in the early age at which the disease begins. The authors' cases dated back either to birth, or to the first 15 months of life, with the exception of one patient in whose case the symptoms were first noted at six years of age. When it is remembered that the infant's skull is relatively soft and malleable, the uniform changes occurring in the skull in this condition may be accounted for. If the bones are soft enough, an actual flattening or even depression of the vault on the side of the lesion may occur. If, on the other hand, the vault is rigid enough to withstand the unequal pressure from the two sides, the osteoblasts of the inner table are unequally stimulated or the normal absorption of the inner table fails to take place and a thickening of the bones of the skull over the defect results. In the region of the sinuses, the process of space elimination occurs by an expansion of these air spaces and a pneumatization of the bones.

The roentgenologic examination revealed a thickening of the cranial vault on the same side as the cerebral lesion; an over-development of the frontal and ethmoid sinuses, and of the air cells of the petrous pyramid of the temporal bone. Encephalography shows enlargement of the lateral ventricle on the affected side, and sometimes of the third ventricle, these structures being displaced toward the side of the cranial lesion. This condition may be distinguished from tumor by the absence of signs of increased intracranial pressure, and by the presence of changes in the vault and sinuses in cerebral hemiatrophy.

J. N. Ané, M.D.

Cysticercosis in Twin Brothers, Aged 13 Years, with a Radiological Study of the Calcified Cysticercus in 12 Cases. W. K. Morrison. British Med. Jour., Jan. 6, 1934, No. 3809, 13, 14.

The author reports the case of a schoolboy, aged 13 years, who was referred for an x-ray examination of the skull, following symptoms which were epileptiform in character. The radiographic examination revealed a normal skull with nine small circular opacities similar to those caused by calcified cysticerci. The limbs of this patient were next examined by means of the x-ray, and 23 calcified cysticerci of various shapes were discovered. This boy had a history of six mild fits, the first of which occurred at the age of 18 months. X-ray examination of the twin brother of the patient, although this boy had never had fits, showed a calcification in the region of the right side of the neck which resembled cysticercus. It was also of interest to note that the patient and his family had spent two and one-half years in India.

In a series of 12 cases of cysticerosis, calcified cysticerci were found in the brain in only two patients. The amount of calcium deposit, and the time taken to calcify, depend on several factors not well understood at this time. The opaque shadows seen in these cases represent the following: The calcifying or calcified scolex, the true bladder in which development occurs; the remains of the fluid contents of the true bladder; the outer cyst wall provided by the tissues of the host, and the remains of the fluid contents of this outer cyst. The shapes noted resulted from pressure by neighboring structures.

J. N. Ané, M.D.

THE SPINE

Our Experience with Tuberculosis of the Spine. V. Schiller and W. Altschul. Röntgenpraxis, July, 1933, V, 481–487.

Tuberculosis of the spine represents the largest percentage of cases of tuberculosis of the bones. The upper and lower portions of the spine are only rarely attacked; toward the middle of the spine this disease is found much more often, while the lower fourth portion of the dorsal spine is attacked most often (29 in 85 cases). The high percentage of tuberculosis in this area may be explained by the fact that it is exposed to trauma more than any other part of the spine.

The different types of disease may be grouped as follows:

1. Slight changes, representing cloudiness of the bone structure, slight irregularities of the contour, and difference in height of the bodies (3 cases).

2. More marked erosions on the joint surfaces of the vertebræ, usually combined with disease of the corresponding surface of the next vertebra (4 cases).

3. Small defects on the anterior edges of the vertebræ, visible on lateral roentgenograms (2 cases). This proves the importance of a lateral view, which should represent no technical difficulty.

4. Extensive destruction, with compression of vertebræ:

(*a*) Wedge-shaped vertebra, the narrowest point being anterior (9 cases).

(*b*) Marked compression, with protruding of fragmented bone above the normal anterior boundary of the vertebra.

(*c*) Pushing together of two neighboring vertebræ with wedging and healing by "block formation" (14 cases).

(*d*) Healing by formation of bony bridges between the vertebræ (6 cases).

(*e*) Extreme deformities by healing in almost a right-angle (becoming less frequent). These cases (2) showed no symptoms of spinal cord changes.

Only one death occurred (the patient left the institution before the end of the treatment). The other patients were in part cured, in part so much improved that they were able to work. The treatment consists of helio- and roentgen therapy, in combination with orthopedic and dietetic measures.

H. W. Hefke, M.D.

A Case of Nucleus Pulposus Prolapses. Schwede. Röntgenpraxis, July, 1933, V, 515–517.

Since Schmorl's publication in this field so many case reports and publications have appeared that Schmorl's bodies, or prolapse of the nucleus pulposus of the intervertebral discs, are now generally known and recognized by almost every roentgenologist. According to Schmorl, the possibility exists that occasionally such a prolapse may occur after injury; usually, however, in his opinion a continuous chronic strain must be held responsible in the case of young persons (sport, motorcycling, etc.). In the case reported by the author a nuclear prolapse could be seen in the ninth dorsal vertebra, which also showed evidence of an old healed compression fracture (probably due to an injury eight years before). There were also multiple prolapses of nuclear tissue in the lumbar vertebræ. The patient complained of having suffered backache for five years, especially after strain and exercise. According to Brandes, one is justified in considering such prolapse in the immediate neighborhood of a fractured vertebra as direct result of an injury. It seems to the author that the changes in the lumbar spine should be attributed to the same trauma. Most authors believe that these Schmorl's bodies cause no, or very slight, symptoms. However, in some cases slight back symptoms can be explained only by their occurrence.

H. W. Hefke, M.D.

The Roentgenologic Appearance of the Vertebra Plana Calvé and its Interpretation. Federschmidt. Röntgenpraxis, November, 1933, V, 801–805.

Only about 20 cases of vertebra plana, first described by Calvé, have been reported in the literature. The author found 2 in 50 cases of tuberculous spondylitis which he observed from 2 to 3 years. The prognosis of this disease is very favorable, and for that reason it is important to differentiate it from the very similar appearance of tuberculosis. It is impossible to make a definite diagnosis in the first stages. In a girl 4 years of age the first roentgenologic finding was a decrease in the height of the intervertebral disc between the second and third lumbar vertebræ which looked typical for a beginning tuberculous spondylitis. Five months later the third lumbar vertebra was markedly flattened and showed increase in its width; the intervertebral disc was of normal height. In tuberculosis and osteomyelitis the narrowing of the disc is permanent and irreparable. The breaking down of the vertebra takes place very rapidly in Calvé's disease. In the second of the author's cases the characteristic flattening was seen as early as 6 weeks after the beginning of the symptoms. The final deformity of a typical Calvé vertebra should be uniform flattening: other deformities should make one hesitate about the diagnosis. In some cases the diseased vertebra regenerates to a certain extent, contrary to the findings in tuberculosis. Autoptic findings about this disease have not been reported. It may best be explained by a local malacia, comparable with the malacia in Köhler's disease.

H. W. Hefke, M.D.

THE THORAX

The Inferior Accessory Lobe of the Lung. Leo G. Rigler and Lester G. Ericksen. Am. Jour. Roentgenol. and Rad. Ther., March, 1933, XXIX, 384–392.

While autopsy figures indicate the occurrence of a partly or completely formed inferior accessory lobe in either the right or left lung in as high as 45 per cent of cases, Rigler and Ericksen were able to demonstrate the same anatomic variation roentgenographically in 8.2 per cent of unselected chest films. Even so, this indicates a much greater frequency of occurrence and demonstration than the much discussed azygos lobe which occurs with a frequency of only about 1 per cent of unselected cases. Cases have been clinically observed with lower lung pneumonias which involved either the accessory lobe only or the lower lobe proper but not the accessory one. Demonstration of the fissure in the right lung is easier than in the left because of the position of the heart. Differentiation must be made between: an infiltration of the accessory lower lobe from encapsulated mediastinal pleural effusion; from atelectasis of the medial portion of the lower lobe, and, less commonly, from paravertebral abscess and aneurysm of the descending aorta.

J. E. Habbe, M.D.

Multiple Round Shadows in Roentgenograms of the Lungs. Frank Kellner. Röntgenpraxis, November, 1933, V, 806–809.

Multiple round shadows in lung roentgenograms are relatively rare, if not caused by metastases or echinococci. They are probably mostly due to tuberculous foci but may be caused also by other inflammatory diseases. A case is described in which multiple, fairly large, and fairly well circumscribed shadows were found in the roentgenogram of the lungs after the patient had gone through an acute lung disease. Metastases, tuberculosis, echinococci, and syphilis could be excluded clinically. During the course of a few months the lungs became entirely normal. It is concluded that these round shadows represented localized areas of unresolved or slowly resolving bronchopneumonia. This case indicates that one must not think only of metastases, echinococci, and tuberculosis but also of bronchopneumonic processes, when confronted with such shadows.

H. W. Hefke, M.D.

The Treatment of Chronic Empyema. Udo Ellerbroek. Strahlentherapie, November, 1933, XLVIII, 562–569.

The author describes a case of empyema which he treated by roentgen rays. He applies two fields over the fistula, using the following technic: 200 K.V., 1 mm. Cu + 1 cm. Al, 30 cm. F.S.D., 60 r. This dose

is given twice a week, until a total dose of 600 r has been applied. The results were so encouraging that he recommends this procedure for further trial.

ERNST A. POHLE, M.D., Ph.D.

TUBERCULOSIS (DIAGNOSIS)

Communication between the Two Pleural Sacs, with Lungs Showing Tuberculosis Healed after Thoracoplasty. Charles R. Smith and H. S. Willis. Jour. Am. Med. Assn., Oct. 14, 1933, CI, 1224–1226.

This is a case report of a man, aged 35, in whom an attempt to induce pneumothorax on the left side induced pain on the right side and led to the discovery of an interpleural communication. Demonstrable interpleural communications in man are notably uncommon. The anatomic basis of such natural and spontaneous phenomena is not clear; however, the basis for possible rupture or mechanical break does exist in the anatomic structure of the mediastinum. Nitsch described two "weak places" in its structure, one posterior to the upper portion of the sternum at the second, third, and fourth ribs, and the second in the posterior inferior portion of the mediastinum near the level of the eighth rib. In the presence of a pneumothorax with high pressure, the possibility of a pleural tear in either of the weak places must be considered.

C. G. SUTHERLAND, M.D.

Tuberculosis of the Greater Trochanter. Henry W. Meyerding and Rudolph J. Mroz. Jour. Am. Med. Assn., Oct. 21, 1933, CI, 1308–1313.

Spalteholz described 16 bursæ in the region of the hip, and other observers have described as many as 31. Most of these are not constant and are small; the most important are the gluteus maximus bursa over the greater trochanter, the iliopectineal bursa, and the ischiogluteal bursa. The iliopectineal bursa is often directly connected with the hip joint. Tuberculosis of the greater trochanter and the bursa over the trochanter start usually in adolescence and are to be distinguished from disorders of the hip joint and from neoplasms. Adequate treatment consists of radical excision of the diseased bursa and trochanter. Primary infection is usually in the trochanter and may spread by continuity to the bursa. In cases in which apparently only the bursa is involved, perfect healing followed surgical treatment. Evidence of tuberculous disease was found in 73 per cent of the authors' cases: 42 per cent in the lung and 31 per cent in other parts of the body. Roentgenograms showed involvement of the trochanter in 78 per cent.

C. G. SUTHERLAND, M.D.

Multiple Round Tuberculous Foci in the Lungs. H. Meyer-Borstel. Röntgenpraxis, May, 1933, V, 321–329.

Multiple, coinlike, well circumscribed shadows in lung roentgenograms are generally considered as typical for metastases. Lachmann recently described an atypical lung tuberculosis, simulating metastases, the clinical picture and the course of the disease proving the disease to be a tuberculosis. The author has also seen several such cases and reports seven of them. Reproductions of films illustrate his contention that multiple round circumscribed areas of infiltration may be the roentgenologic representation of tuberculous foci. History and clinical findings are given in order to prove the tuberculous nature of these structures. In two cases these round areas disappeared completely, just as a primary infraclavicular tuberculous infiltrate would do. One case was especially interesting, because it showed carcinomatous metastases as well as multiple round tuberculous infiltrations in the lung on roentgenograms as well as at autopsy. The last roentgenogram showed multiple, very small shadows in the right upper and middle lobes and six well circumscribed round shadows, the size of a cherry, in the same area; also three similar shadows in the left lung. While the entire lung pathology was first diagnosed as tuberculosis, this opinion was changed and all lung pathology was attributed to carcinomatous metastases, when metastases were found in the skeleton. Postmortem examination, however, showed (corresponding with the round shadows on the roentgenogram) old cirrhotic tuberculous nodes in the lung, only the fine mottling being due to carcinomatous metastases.

A differential diagnosis between metastatic and tuberculous round infiltrations is often impossible without the history and clinical findings. From the number of these shadows, their shape, size, and density, it is impossible to draw any conclusions. Occasionally the round tuberculous foci may show a less defined border and small irregularities of the edges.

H. W. HEFKE, M.D.

TUBERCULOSIS (THERAPY)

Advanced Bladder and Urethral Tuberculosis: Treatment by Ureteral Transplantation following Preliminary Colostomy. Reed M. Nesbit. Am. Jour. Surg., December, 1933, XXII, 547–549.

Progression of bladder lesions following nephrectomy for unilateral renal tuberculosis offers a serious obstacle to recovery. When complicated by tuberculous stricture of the urethra, this condition is likely to terminate fatally. Putting the bladder at complete rest by diversion of the urinary stream constitutes the soundest policy of treatment. The most satisfactory methods for accomplishing this are ureterostomy or ureteroenterostomy. Of these, the latter is the more desirable procedure but carries the distinct hazard of infection in these patients, who are, at best, poor operative risks and tolerate infections poorly. Colostomy as a preliminary measure before ureteral transplantation is proposed as a method for eliminating this hazard of infection. A case successfully treated by this method is presented.

DAVIS H. PARDOLL, M.D.

Roentgen Therapy of Tuberculous Glands. W. Baensch. Strahlentherapie, December, 1933, XLVIII, 766–770.

Heavily filtered roentgen rays (0.5 Zn + 3 Al) in doses of from 30 to 50 per cent E.D., given three times at intervals of 8 days, are recommended by the author. According to the literature, the percentage of cure varies from 40 to 90 per cent.

ERNST A. POHLE, M.D., Ph.D.

Successful Removal of an Entire Lung for Carcinoma of the Bronchus. Evarts A. Graham and J. J. Singer. Jour. Am. Med. Assn., Oct. 28, 1933, CI, 1371–1376.

Primary carcinoma of the lung almost always arises in a bronchus. Up to the present time the prognosis has been almost uniformly bad because of the complete futility of any methods of treatment other than surgical excision. There is no record in the literature of the successful treatment by radiotherapy of a single case in which the pathologic evidence has been incontrovertible and in which a five-year period without recurrence has elapsed between the treatment and the time of reporting the case. The authors report apparently the first case in which an entire lung has been successfully removed for a carcinoma.

C. G. SUTHERLAND, M.D.

The Rôle of the Ureter in Renal Tuberculosis. Robert V. Day. Am. Jour. Surg., December, 1933, XXII, 542–546.

In dealing with this subject the author arrives at the following conclusions: Where a tuberculous lesion has advanced to the renal pelvis or collecting tubules, renal tuberculosis never completely heals, because of the handicap of hindered drainage and back-pressure, due to tuberculous changes in the ureteral wall. That is to say, aside from other possible reasons, a tuberculous kidney excreting tubercle bacilli cannot recover because an incurably strictured ureter interferes with normal drainage and peristalsis. When complete healing does occur, the tuberculous process is limited to the cortex, *i.e.*, it has never been found to extend to a pyramid or collecting tubules. Until the tuberculous process has extended to a calyx or the collecting tubules, pus and tubercle bacilli of renal origin will not be found in the urine, and, therefore, up to this time, renal tuberculosis may not be said to be "clinically established."

DAVIS H. PARDOLL, M.D.

TUMORS (DIAGNOSIS)

Some Evidences of Intracranial Disease as Revealed by the Roentgen Ray. Charles Wadsworth Schwartz. Am. Jour. Roentgenol. and Rad. Ther., February, 1933, XXIX, 182–193.

Intracranial calcifications are classified by the author as to form in three groups: punctate, linear, and amorphous.

Approximately 50 per cent of all intracranial tumors fall in the glioma group. While only about 13 per cent of these show direct evidence of their presence and location by calcification, a highly probable diagnosis is possible in about 50 to 60 per cent because of indirect signs. Such tumors often reach tremendous size without causing signs of increased pressure. Pressure signs may develop quite rapidly, especially in a child's skull, and conversely may disappear rapidly with release of the pressure.

Pituitary adenomas are variously reported as occurring with a frequency of from 5 to 19 per cent. Local pressure changes are the rule, with the suprasellar cysts often showing calcification.

Temporal lobe tumors often produce asymmetrical erosion of the sella: petrous ridge atrophy may be caused by acoustic neuromas or by metastatic disease and osteochondromas; meningiomas usually show local increased vascularity and may show osteoporosis or marked hyperostosis; calcifications of crescentric form over the sella, with sellar destruction, constitute changes characteristic of carotid aneurysm.

The article includes many excellent illustrations.

J. E. HABBE, M.D.